Transactions of American Society for Steel Treating

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SPECIAL FEATURES

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TRANSACTIONS
of the
American Society for Steel Treating

Vol. III Cleveland, June, 1923 No. 9

PROGRESS IN FATIGUE OF METALS INVESTIGATION

DURING the year 1922, definite and important progress was made in the experimental work of the Fatigue of Metals Investigation at the Engineering Experiment Station of the University of Illinois. Engineering Foundation has continued its co-operation and the committee of the National Research Council has advised on program and report. A second report giving results and conclusions in detail, the Bulletin No. 136, of the Experiment Station has recently been distributed.

Interest in this investigation has spread and its practical value has come to be more widely appreciated. During 1922 outside funds for support of the project came wholly from the General Electric Co. Its officers have expressed high satisfaction with the work done.

Extension for two years is assured by the provision of additional funds to the amount of $30,000. The University of Illinois, the National Research Council and Engineering Foundation will continue to co-operate. The following industries will participate financially and in other ways: General Electric Company by a substantial addition to its preceding investment of $30,000; the Allis-Chalmers Manufacturing Company, the Copper and Brass Research Association, representing the most important producers and manufacturers of copper and its alloys, and the Western Electric Company. Several other companies are expected to join, in addition to a number mentioned in the first report (Bulletin No. 124, of the Engineering Experiment Station), which contributed materials and services of considerable value.

On the new part of the program are tests of steels at high temperatures, such as obtain in modern steam-engineering equipment and in internal-combustion engines, and a study of nonferrous metals, particularly the copper alloys.

The investigation continues under the immediate charge of Prof. H. F. Moore and has the general supervision of Prof. Arthur N. Talbot, as the head of the Department of Theoretical and Applied Mechanics, in the Engineering College of the University of Illinois.

CONFERENCE PERTAINING TO THE MANUFACTURE AND USE OF SCIENTIFIC INSTRUMENTS RECENTLY HELD

A CONFERENCE of men interested in the use or the manufacture of scientific instruments and apparatus was held recently at the headquarters of the National Research Council in Washington, D. C.,

at the call of the Council. It was attended by members of government scientific bureaus, scientific societies, universities, the Association of Scientific Apparatus Manufactures and individual firms. Dr. Burgess, director of the Bureau of Standards, presided.

A committee appointed by the chairman brought in a report which was adopted. This proposed that a committee of apparatus makers and users should be formed under the Research Extension division of the Council. This Committee is to consist of one representative from each of the following technical societies and organizations:

American Chemical Society, American Physical Society, American Institute of Electrical Engineers, Optical Society of America, American Electrochemical Society, American Ceramics Society, the Association of Educational Buyers, the American Society for Testing Materials, the Engineering Chemists Association, the American Society for Steel Treating, the Society of Automotive Engineers, and two representatives from the Bureau of Standards and the National Research Council and six representatives from the Association of Scientific Apparatus Manufacturers of the U. S. A. with members at large to be appointed by this committee.

The following were appointed to serve as members-at-large until their successors are chosen:

Hermann Kellner of Bausch & Lomb Optical Company, A. L. Day of the Corning Glass Works, H. B. Williams of the Society of Automotive Engineers, H. E. Ives of the Westetrn Electric Company and C. E. K. Mees of the Eastman Kodak Company.

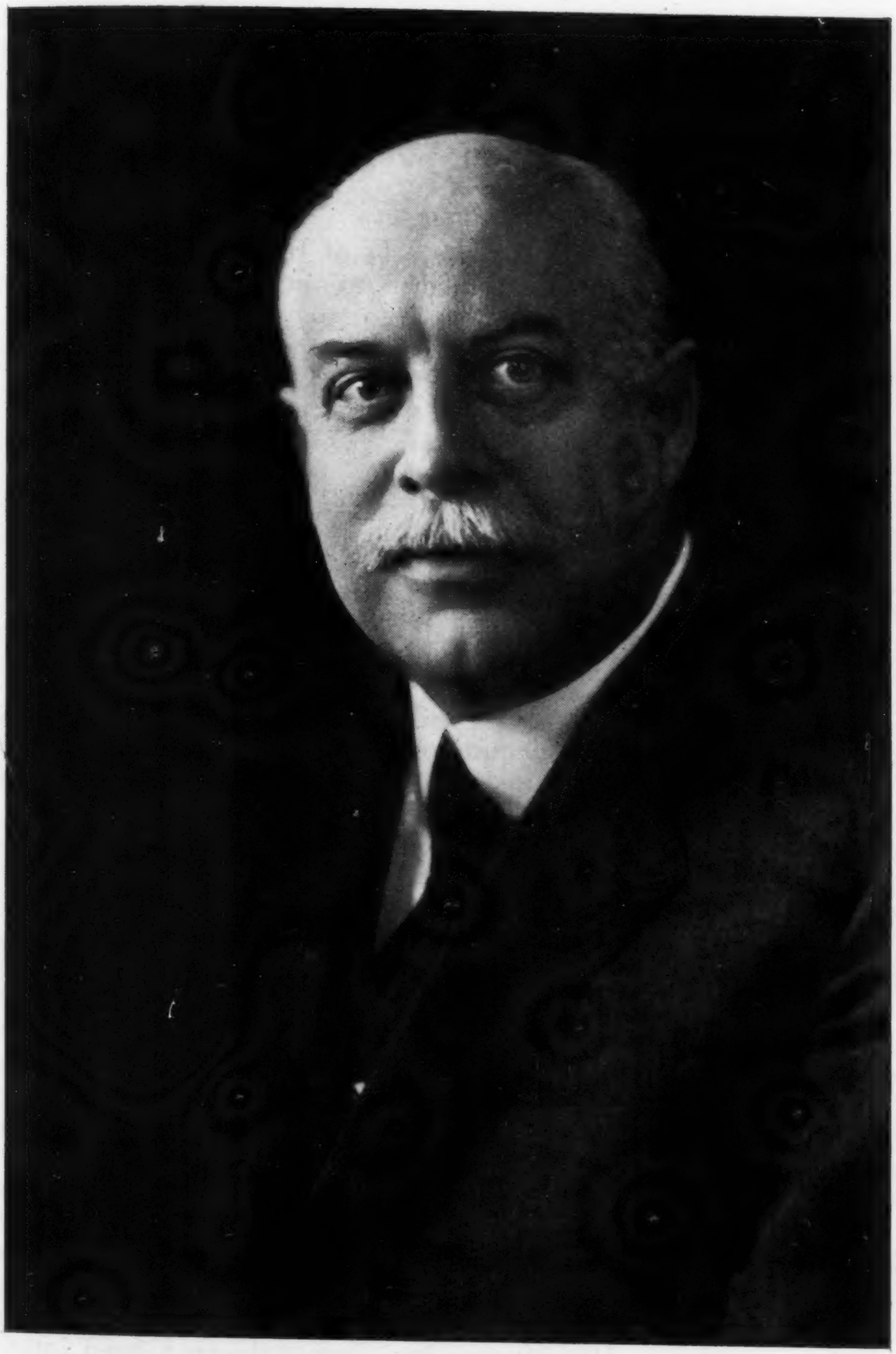
The following were selected to act as an executive committee until their successors are chosen by the main committee:

W. M. Corse of the National Research Council, chairman; Paul Moore of the National Research Council, secretary; W. D. Collins, Geological Survey, F. K. Richtmyer, Cornell University; M. E. Leeds, president of the Association of Scientific Apparatus Manufacturers; John Roberts, secretary of the Association of Scientific Apparatus Manufacturers and G. K. Burgess, director of the Bureau of Standards.

It was agreed that there should be held at least one meeting a year of the general committee, and it is hoped that this can be arranged to take place on the third Thursday in April. This meeting is to be open to all interested. It was decided that the executive committee named should consider the proceedings of the conference and initiate any projects which might seem advisable.

Dr. Vernon Kellogg in welcoming the conference, spoke of the importance of little things, and indicated the progress science had made with the development of the instruments for learning the truth.

The discussion—for the whole purpose of the conference was to bring face to face in a frank conference men interested in the use, the manufacture and the sale of apparatus, centered around (1) Apparatus supply, under the heads importation, domestic apparatus manufacture, instrument shop of research and college laboratories, manufacture of special apparatus not now made in the United States; (2) Standardization of apparatus, under the heads of limitation of types and sizes, standardization of parts, standardization of methods; (3) information service, under the heads—sources of information, finding list, scientific bulletin concerning apparatus and use and (4) Inspection service.



GEORGE KIMBALL BURGESS
Nominee for National President of the Society

REPORT OF NOMINATING COMMITTEE

To the Secretary of the American Society for Steel Treating

The National Nominating committee, meeting according to the constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office:

President—George Kimball Burgess, Washington, D. C.
Second Vice President—Robert M. Bird, Bethlehem, Pa.
Treasurer—Zay Jeffries, Cleveland.
Director—J. Fletcher Harper, Milwaukee.

According to Section 10 of Articles VII of the by-laws, we are enclosing the written consent of these gentlemen to their nomination.

Yours very truly,

NATIONAL NOMINATING COMMITTEE
American Society for Steel Treating
(Signed) JEROME STRAUSS
C. B. SWANDER
C. E. McQUIGG
H. J. STAGG, Chairman.

Biography of Nominees for Offices in the National Society

George Kimball Burgess

Nominated for National President of the Society

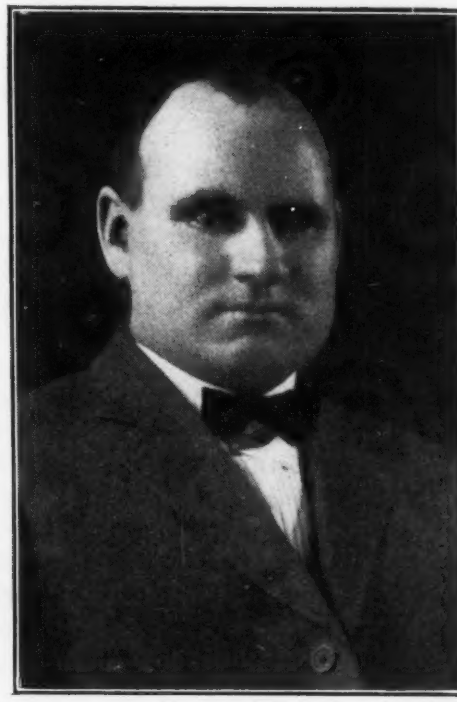
BORN at Newton, Mass., Jan. 4, 1874, having descended from Puritan ancestry, he received his early education in his native city receiving his first degree from the Massachusetts Institute of Technology, where he was instructor in physics for two years after his graduation. Going to Paris he completed his graduate work and received the degree of Doctor of Science at the University of Paris. Upon his return to the United States he became instructor at the University of Michigan for one year, and at the University of California for two years, after which he went to Washington, D. C., and entered the Bureau of Standards as associate physicist and was placed in charge of pyrometry. Out of this grew the division of metallurgy which was established in 1913 with Dr. Burgess in charge as chief physicist, in which capacity he continued until April 23, 1923, when President Harding appointed him as Director of the Bureau of Standards succeeding Dr. Stratton.

Dr. Burgess' acquaintance with the French language has borne fruit in the translation of Duheim's "Thermodynamics and Chemistry," and the publication of "Reserches sur la Constante de Gravitation." Perhaps his best known book is the translation of LeChatelier's work on the "Measurement of High Temperature," which later being enlarged and modernized by him, became the standard English work on pyrometry. While temperature measurement is not one of the phases of the metallurgical division of the Bureau of Standards, nevertheless Dr. Burgess has always shown a keen interest in pyrometry and has never missed a timely opportunity to emphasize the necessity for accurate thermal control in modern metallurgical operations. He has made many technical and scientifical contributions to the numerous scientific societies. Dr. Burgess is a member of the American Society for Testing Materials of which he is now president; the National Academy of Sciences; the American Institute of Mining and Metallurgical Engineers; Iron and

Steel Institute of Great Britain; the Washington Academy of Sciences and the Philosophical Society of Washington, of which he is past-president, the French Physical Society and the American Society for Steel Treating.

Of his many other activities he is chairman of the Board of Federal Specifications of the Bureau of the Budget which has charge of preparing specifications for materials purchased by the government, and he is a member of the National Research council. He represents the Department of Commerce in dealing with the preparation of standards of engineering materials and practices in connection with the work of the American Engineering Society Committee.

ROBERT M. BIRD
Nominee for 2nd Vice President of the Society



ZAY JEFFRIES
Nominee for National Treasurer of the Society

Robert M. Bird

Nominated Second Vice President of the Society

BORN at Bethlehem, Pa., Sept. 17, 1882, he was graduated from Lehigh University in 1902 with the degree of M. E.

Since his graduation he has been with the Bethlehem Steel Co. as superintendent of treatment departments, superintendent of Lehigh merchant mills, metallurgist and now as engineer of tests at the Bethlehem plants.

Mr. Bird has been very active in the art and sciences of metallurgy, having memberships in the American Institute of Mining and Metallurgical Engineers; American Society for Testing Materials; Society of Automotive Engineers—Steel Standards Division; American Iron and Steel Institute; British Iron and Steel Institute and the American Society for Steel Treating.

Zay Jeffries

Nominated Treasurer of the Society

BORN at Willow Lake, South Dakota, April 22, 1888, he was graduated from the South Dakota State School of Mines, Rapid City, S. D., in 1910 with the degree of Bachelor of Science in Mining Engineering. In 1914 he received the degree of Mining Engineer at the same school. Between the years 1911 and 1916 he was instructor in metallurgy at Case School of Applied Science, Cleveland, and in 1916 and 1917 was appointed Assistant Professor of Metallurgy at the same school.

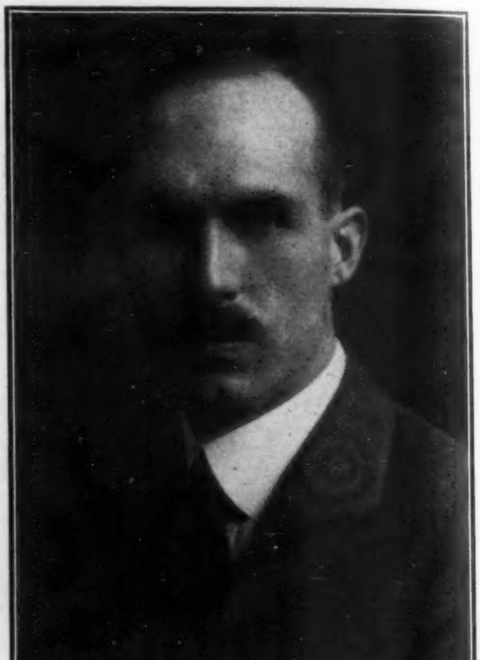
At the present time Dr. Jeffries is in charge of the Cleveland Section of the Research Bureau of the Aluminum Company of America and is consulting metallurgist for the National Lamp Works of the General Electric Co.

J. Fletcher Harper

Nominated Director of the Society

ATTENDED the University of Wisconsin for three and one half years, taking electrical engineering, following which he served a special apprentice course at the Allis Chalmers Mfg. Co. Was connected with the Northwestern Mfg. Co., Milwaukee for one year, returning to the Allis Chalmers Mfg. Co. in July 1916 to take charge of the heat treating departments. In Sept. 1918 he was made assistant superintendent of the forge department in the same plant. In April 1921 he was made research engineer of the manufacturing department of the Allis Chalmers Mfg. Co., which position he still holds.

Mr. Harper served as a member of the board of directors of the American Steel Treaters Society, 1919-20.



J. FLETCHER HARPER
Nominee for Director of the Society

VOLUME III TRANSACTIONS COMPLETED

THE June issue of TRANSACTIONS completes Volume III. Included in the June issue is the author and subject index for Volume III.

All of those who desire to have their separate copies bound in accordance with the style which has been used in binding Volumes I and II, may forward their copies to the Executive Offices of the Society, 4600 Prospect Ave., Cleveland, together with $2.00 and they will be bound and returned to the owner promptly.

We urge that all of our members avail themselves of this opportunity of having this work done at this low cost as we are sure that TRANSACTIONS in the bound form will be of greater service and will make an invaluable addition to your library.

THE MANUFACTURE AND INSPECTION OF LEAF SPRINGS

By H. G. Peebles

Abstract

This paper deals with the manufacture of leaf springs for use in the automotive industry. The author has reviewed one of the largest plants devoted to the production of springs and conducts his readers on a short journey through the plant pointing out those operations which are of prime interest.

The warehouse having a capacity for about 10,000 *tons of steel is one of the salient points of interest, because it is here that the steel is unloaded from the cars, sorted, sampled, tested, and piled in its proper bin. Untiring vigilence in receiving steel in the warehouse, combined with an adequate system of records practically eliminates the factor of defective steel in production.*

The author discusses the various microstructures and imperfections found in spring steels, illustrating them with photographs. Testing methods are likewise briefly reviewed.

Manufacturing methods, furnaces, electrical control of furnaces, mechanical quenching machines and the final capacity testing of springs is covered by the paper.

YOU are probably all familiar with the wonderful strides made in the quantity production of parts, in the automobile industry during the past decade. The manufacture of leaf springs, which constitute a very important part of an automobile, likewise has had to undergo revolutionary changes to keep pace with automobile production and their rigid requirements. In this paper, the author will give you an idea of how the chassis springs on your car are made today, in some of the most up-to-date plants, by taking you on a short inspection trip in one of the largest of these factories.

In beginning our trip, we will first visit the steel stock warehouse, which is conveniently located adjacent to the railroad siding where the cars may be unloaded with the minimum of handling of the incoming steel. Fig. 1 shows the stock bins arranged in the warehouse. The steel is handled by means of the overhead crane which is also shown in this picture.

Not many years ago these 25-foot bars were handled separately and by hand. While this method was alright for small production, it would be absolutely inadequate today, when as much as eight or ten carloads are often unloaded during one day. In addition to handling the incoming stock the crane, at the same time supplies five shears with material thus adding another two and a half carloads to its days work. In this picture you see the largest stock of leaf spring steel in the world, the capacity of these bins totaling about 10,000 tons, or 200 carloads. In these bins it is necessary to keep about 125 kinds and sizes of steel ranging from 1½ to 5 inches in width, and from 3/16 to ½ inch in thickness, of both carbon and alloy analyses, as well as several sizes of dead soft stock for making clips. This enormous stock is necessary

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A paper presented before the Detroit Chapter of the Society. The author, H. G. Peebles is metallurgist with the Detroit Steel Products Co., Detroit, Michigan.

to tide over the periods when there is a steel shortage or railroad trouble. At such times you automobile men may be forcibly reminded of the lines:—

For want of a nail, the shoe was lost;
For want of a shoe, the horse was lost;
For want of the horse the rider was lost;
For want of the rider, the battle was lost;
And all for the want of a horseshoe nail.

Except that in this case it may be wheels, bodies, springs, or some other important part. Except for the labor part of it—the running of the crane and

Fig. 1—Warehouse Showing Steel Spring Stock Arranged in Numbered Bins. The Overhead Crane Serves the Purpose of Handling the Steel in Placing It in the Proper Bins as Well as Supplying the Shears With Steel for Production.

the handling of the chain around the bundles—all details of physical inspection, assignment, shear records and perpetual inventory are easily handled by one man.

Identity of Steel Accurately Maintained

Now a word here about the unique way in which the records of this stock are kept so as to take care of any possible trouble that might get past the routine inspection of the raw stock. You will notice that the bins are numbered. The contents of the bins are kept on record, not only in the form of a perpetual inventory as to the quantity of each size, but also in such form that the locations, amounts, and sizes of each heat and each car are known. Each heat of steel is given a laboratory serial number. If the same heat is received in three sizes in four cars, all these entries will appear on the one sheet in the laboratory. The daily record of steel sheared includes for each order the heat number, the bin number, the size and the kind of steel used on each plate. It should be stated here that the leaves or plates of a chassis spring are numbered consecutively from the long one down to the short one, the long leaf, which ordinarily has an eye at each end, being the main leaf, the back, or plate No. 1. Occasionally there is an extra plate placed on the inside of the camber or arch of the main leaf. This has no number, but is called an auxiliary plate. Under this arrangement, when trouble is encountered in production, for instance, a few soft plates in one job, indicating

a mixed heat of steel from the mill, the record of the steel sheared on that order will give the heat number, and the laboratory sheet will give the necessary data to enable locating all the remainder of that heat or that car, so that it can be resampled. Not only does this prevent further expensive trouble, but it enables the rejection of mixed stock even when the original sampling failed to detect the defective material. It also enables the stopping of all other orders in the process of manufacture, on which the same steel was used. Another unique point in this connection is that the stock clerk is held accountable only to the metallurgical department. This is the only arrangement by which this method of handling heats could be carried out successfully.

Inspection of Raw Stock

The inspection of raw stock starts when the notice of shipment is received in the laboratory. This contains the amount of each size and each heat, and the quoted analyses. This data is passed on to the stock clerk before the car is received, along with instructions as to sampling. The physical inspection of the incoming steel includes testing a large number of bars for width, thickness, and concavity, and examination for pipes, surface defects, and straightness. The width is tested with fixed maximum and minimum gages unless trouble is encountered. For gage and concavity it is necessary to use micrometers, as a few thousands of an inch may seriously affect the flexibility tests of the final inspection. In connection with the test for concavity it should be mentioned that the spring steel used in chassis springs is not flat, but is from five to thirty thousandths of an inch thinner at the center of the bar than it is at the edges, the concavity specified depending upon the width. This is necessary to enable perfect fitting of the leaves. Of course, too much concavity would weaken the spring leaves. The number of regular samples taken on the raw stock runs from one sample from each size of each heat in the car, where the customer has inspected the billets and analysis before rolling, up to as high as several samples from each bundle in case of trouble or a suspicion of trouble. In addition to these, numerous samples are taken for heat treatment tests. Each of these regular samples is subjected to complete chemical analysis, micro-analysis, and various physical tests.

The physical test pieces pass through the heat treating furnaces as coupons with production, and are then subjected to Brinell, bend and fracture tests, and occasionally to tensile and vibratory tests. These coupons are filed so that they are available for microsections, as a check upon heat treatment, although this is not necessary, once the time and temperature for a kind and size of steel have been established.

Microscopic Examinations

In the microscopic analysis, the sample is normalized in a furnace having a reducing atmosphere and cooled slowly enough to develop the pearlite and either ferrite or cementite, as the case may be. The section which is polished and examined under the microscope covers a little over half of the cross section of the bar, or all of the center of the bar and one edge. This section is examined for pipes, slag or dirt, segregation, depth of scratches or seams, and decarburization, and the carbon content is estimated. The use of the microscope is deemed necessary for routine inspection, since, in a product which is made to withstand vibrations, segregated or dirty steel is as bad as incorrect analysis.

Before going into the details of the manufacturing of leaf springs we will

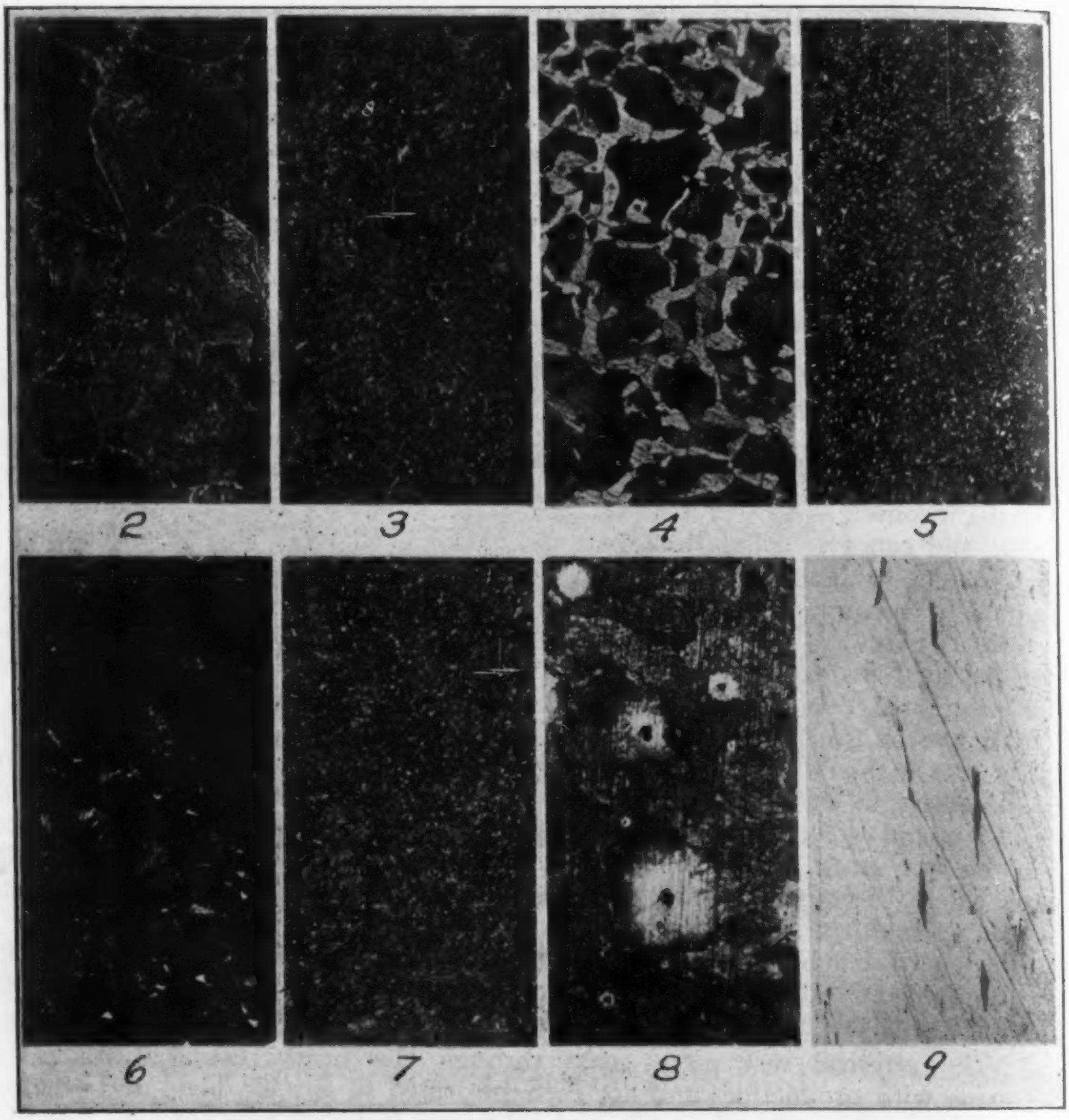


Fig. 2—Normalized Carbon Spring Steel Containing About 1 Per Cent Carbon and 0.4 Per Cent Manganese. Fig. 3—Same as Fig. 2 After a Proper Heat Treatment. Fig. 4—Normalized Silico-Manganese Spring Steel Having an Approximate Analysis of 0.5 Per Cent Carbon, 0.7 Per Cent Manganese and 2 Per Cent Silicon. Fig. 5—Same as Fig. 4 After a Proper Heat Treatment. Fig. 6—Normalized Chrome-Vanadium Spring Steel Having an Approximate Analysis of 0.5 Per Cent Carbon, 0.8 Per Cent Manganese, 1 Per Cent Chromium and 0.17 Per Cent Vanadium. Fig. 7—Same as Fig. 6 After a Proper Heat Treatment. Fig. 8—Dirty Steel. Fig. 9—Dirty Steel Showing Layers of Slag. This Specimen is a Cross-section and Not a Longitudinal Section. All Photomicrographs Have a Magnification of $\times 100$.

first look at a few of the various structures of steels as seen through the microscope. These are shown in Figs. 2 to 14. Fig. 2 shows a normalized carbon spring steel containing about 1.0 per cent carbon and 0.4 per cent manganese, and Fig. 3 shows it after a proper heat treatment.

Fig. 4 shows a silico-manganese spring steel in the normalized condition. The analysis specified for this steel varies considerably, but will average about 0.5 per cent carbon, 0.7 per cent manganese, and about 2.0 per cent silicon, and is shown in Fig. 5 after a proper heat treatment.

In Fig. 6 is shown a chrome vanadium spring steel, normalized. Speci-

fications also vary somewhat for this type of steel, but will average about 0.5 per cent carbon, 0.8 per cent manganese, 1.0 per cent chromium, and 0.17 per cent vanadium. The microstructure of this steel after a proper heat treatment is shown in Fig. 7. Chrome molybdenum steel appears the same as chrome vanadium and has the same analysis, except that the vanadium is replaced with about 0.3 per cent molybdenum.

No photomicrographs of chrome-silico-manganese steel are shown, but the normalized structure is about an average of that of silico-manganese and chrome vanadium steels, as would be expected. An average analysis would be about 0.5 per cent carbon, 0.7 per cent manganese, 0.7 per cent chrome, and 0.5 per cent silicon.

Figs. 8, 9 and 10 show some of the defects that only the microscope can reveal. Figs. 8 and 9 show the microstructure of dirty steel. Fig. 9 shows layers of slag in a specimen of steel when the section was cut crosswise of the bar and *not* lengthwise. Neither was the photo taken at the center of the bar; but it represents most of the cross section of all eight samples taken in rejecting one heat of steel.

An example of excessive decarburization is shown in Fig. 10. Such a condition may reduce the effective strength of the plate to a noticeable degree if it penetrates too far. This may be encountered on the raw steel, or, more frequently, it comes from excessively high temperatures used in the old method of heat treating.

In Fig. 11 is shown a macrograph of a quenched test piece of carbon steel, several heats of which had to be rejected on account of hard and soft spots. The black spots are pure troostite and are soft, and the white areas are almost pure martensite and glass hard.

Fig. 12 shows a macrograph of carbon segregation. The white area in the left center of the upper sample showed about 1.15 per cent carbon, while the dark area at the right showed about 0.9 per cent. Fig. 13 shows what actually happened to the piece when it was quenched. Due to unequal expansion and contraction the core actually broke away from the shell.

A few other items that have to pass laboratory inspection, are bronze bushings, nickel steel center bolts, and clip steel. These are subjected to chemical analysis and examination under the miscroscope. Clip steel also has to pass the flat, cold bend test. Nickel steel bolts also have to be examined for heat treatment. If they are too hard the heads fly off; if too soft, they stretch.

Manufacture of Leaf Springs

With this brief review of the responsibility of the metallurgical department and incoming inspection department in inspecting, sorting and segregating the raw stock for the manufacture of leaf springs we will now pass on to the actual manufacture of the springs. After the steel has been sheared to the desired lengths, it is passed on to various other machines. The main leaves go to the eye machine, then to the machine which mills the eyes to width, and then to another which reams them to the correct internal diameter. On the eye machine are guides which insure the eye being at right angles to the plate. When the eyes leave the milling machine they are correct in width to within a few thousandths of an inch. Inspection here is important in preventing a loose fit and consequent side-play where the spring is fastened to the shackle or the chassis. The operations to which the other plates are

subjected are, punching, nibbing, diamond pointing, rolling and trimming. Plates used to be kept from slipping in the assembled spring by the use of nibs near the center of each plate, but this has been almost entireiy replaced by the use of the centerbolt. Likewise it used to be customary to roll the ends of the plates to thinner cross-section to allow the even distribution of the load,

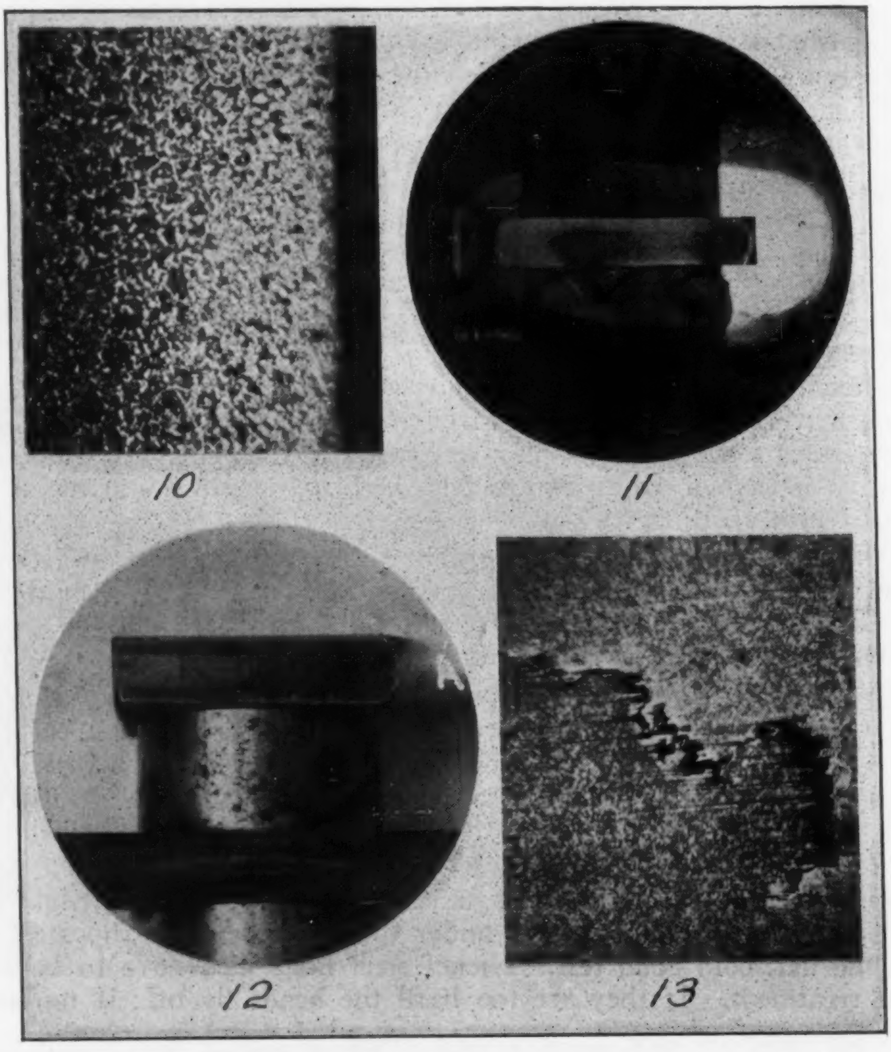
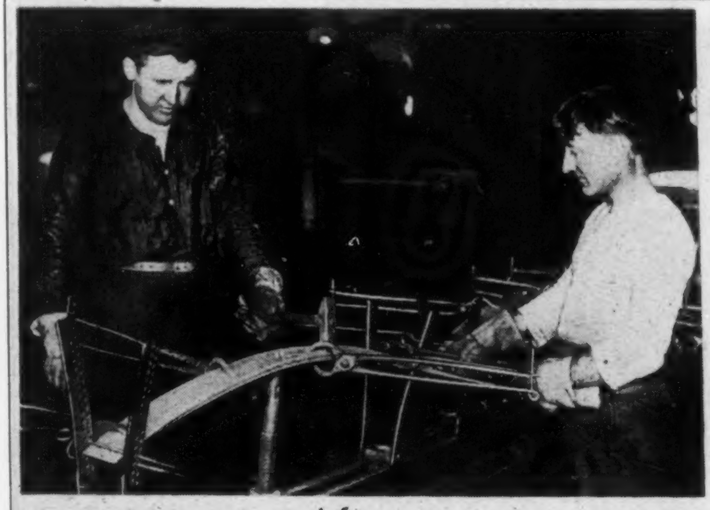


Fig. 10—Photomicrograph of Steel Showing Excessive Decarburization. The Dark Area at the Left is the Normal Structure. The Light Area at the Right is the Decarburized Layer. ×100. Fig. 11—Macrograph of a Quenched Test Piece of Spring Steel Which Had Been Rejected Due to Hard and Soft Spots. The Black Spots are Pure Troostite and are Soft, and the White Areas are Almost Pure Martensite and Glass Hard. Fig. 12—Macrograph Showing Carbon Segregation in Spring Steel. The White Area in the Left Center of the Upper Sample Showed About 1.15 Per Cent Carbon While the Dark Area at the Right Showed About 0.9 Per Cent Carbon. Fig. 13 Shows What Actually Happened to the Piece When It was Quenched. Due to Unequal Expansion and Contraction the Core Actually Broke Away From the Shell.

until someone discovered that almost exactly the same action could be obtained by simply trimming a little triangle of steel off from each corner of the plate. This process is called diamond pointing.

From these operations the next step is the forming and heat treating of the spring leaves. Fig. 14 shows the old method of forming, cambering or pinching the plates by hand. Carriage springs of the olden days used to be

formed this way from a high heat and when they had cooled to the proper shade of red they were thrust into water for a few seconds and then withdrawn so as to allow the remaining heat to draw the temper. Of course, they used lower carbon steel, but today we keep away from even traces of



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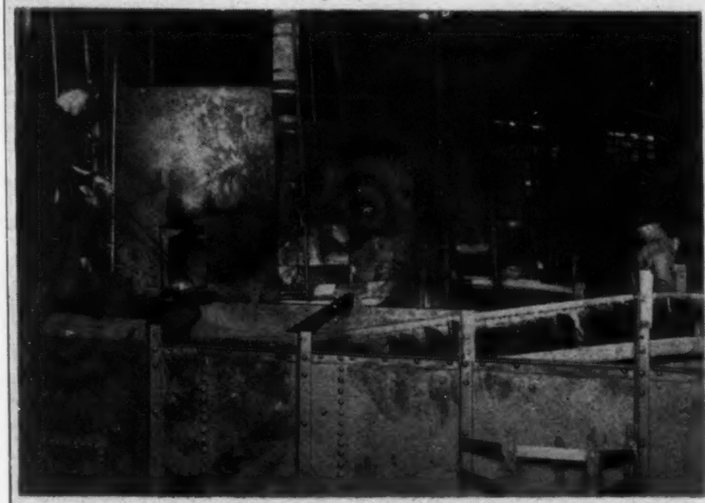

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Fig. 14—Showing the Old Method of Forming, Cambering, or Pinching the Plates by Hand. Fig. 15—Showing a Rotating Hearth Furnace Which Has Given Good Service in Reheating Hand-Formed Plates. The Spring Leaves are Fed in on Edge at the Door at the Right and are Taken Out About One-Half Hour Later from the Door at the Left, After Traveling Almost a Complete Revolution of the Hearth Through Gradually Increasing Temperature Zones.

water. As soon as they started to make automobile springs this method was changed to the following procedure: Heat to *about* 1700 degrees Fahr. (emphasis on the *about*), pinch or form, quench in oil until nearly cold, then draw by the so-called flash method of putting the quenched plate back into the same furnace and leaving it until the oil had burned off! It may sound odd, but there were a few men in the country who could make pretty

fair springs this way. However, it would take about 1000 men with this good judgment for the day shift, and another 1000 for the night shift to keep this one factory going, not to mention the 500 furnaces that would be necessary! Later this routine was changed by eliminating the flash draw and substituting

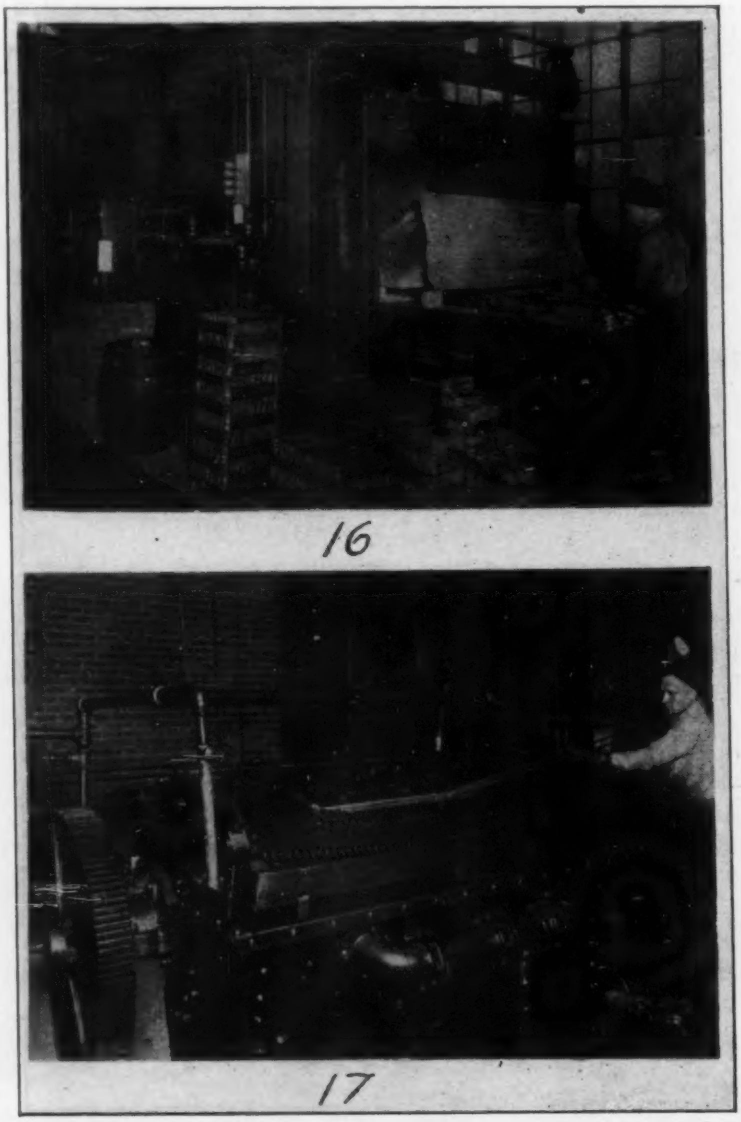

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Fig. 16—One of the Latest Types of Continuous Furnaces for Heat Treating Steel Spring Leaves. There are Several Walking Beams Extending Lengthwise of the Furnace and are Operated by a Cam Through Slots in the Floor of the Furnace. The Spring Leaves are Lifted Clear of the Floor, the Beams Then Move Forward Several Inches and the Entire Contents of the Furnace are Deposited Again on the Floor of the Furnace a Few Inches Ahead of Their Previous Position. Fig. 17—Quenching Machine Which Receives the Heated Plates from the Furnace in Fig. 16 and Clamps Them Into the Proper Shape and Then Quenches Them in the Oil Bath.

a reheat in a furnace at a temperature of about 1000 degrees Fahr. This procedure is still followed in a few plants, but the high initial temperature necessary produces such a coarse grain in the steel, that it is not to be recommended. There is also a large percentage of soft plates, due to their cooling a little too far before entering the oil. Where hand forming is still

used, it is now customary to allow the plates to cool in the air after the cambering operation, then to reheat them to the correct temperature, quench in oil, and draw in either a low temperature furnace or in a salt bath. In the larger plants hand pinching is used only on jobs too small to warrant a machine set-up.

Heat Treatment

Before passing on to the heat treatment, the tempering oil system should be mentioned. All quenching tanks are connected with a circulating system of large capacity in which are large banks of cooling coils over which fine

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Fig. 18—Showing Control Valves, Operating Panels and Pyrometric Recorder Which Constitute the Automatic Temperature Controlling Mechanism on Furnace Shown in Fig. 16. Fig. 19 Shows the Discharge End of an Endless Conveyor Type of Furnace Used to Draw the Temper of Quenched Spring Leaves.

streams of water flow, so that the temperature of the entire system, is kept constant within a few degrees. All tempering oil is tested before it is unloaded, to insure absolute uniformity. All tanks are tapped daily to remove traces of water that settle out.

In Fig. 15 is shown a furnace with a rotating hearth which has given good service in reheating hand-formed plates. The spring leaves are fed in on edge at the door at the right, and taken out about half an hour later from the door at the left, after traveling almost a complete revolution of the hearth through gradually increasing temperature zones. The temperature within this furnace is recorded from five thermocouples.

The feeding of the plates of raw steel into one of the latest types of continuous furnaces for heat treating work is shown in Fig. 16. The plates are handled in rotation, in the order in which they are finally assembled. There are three or four walking beams extending lengthwise of the furnace and operating by a cam action, through slots in the floor of the furnace. The spring leaves are lifted clear of the floor, the beams then move forward several inches, and the entire contents of the furnace are deposited again on the floor of the furnace a few inches ahead of their previous position. As the plates reach the other end of the furnace they are taken out through the tiny side door shown at the right in Fig. 17, and placed between the jaws of the machine. The operator then trips a lever, the jaws close, and the drum revolves until the redhot plate is submerged in the oil.

It remains clamped in the jaws under the oil until it is nearly the same temperature as the oil. About three or four seconds elapse between the time the plate leaves the hot furnace and the time it enters the oil.

Fig. 18 shows the control valves, operating panels, and recorders which constitute the automatic temperature controlling device used by the largest spring manufacturing plant on all of its cambering furnaces. The recorder is fitted with two sets of maximum and minimum contacts, which act inde-

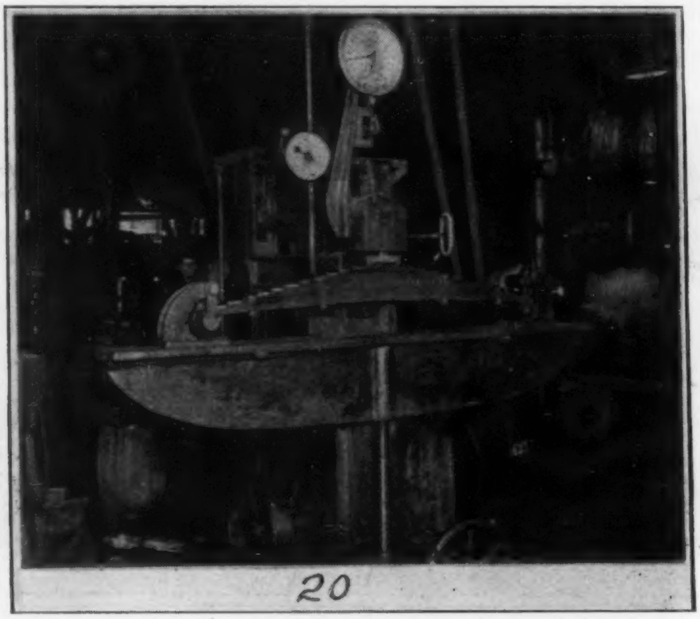

Fig. 20—Capacity Testing Machine for Determining the Load and Deflection of Finished and Assembled Leaf Springs.

pendently of each other. The action of one set of contacts is controlled by a thermocouple located in the preheating end of the furnace. This set, in turn, controls the relay and panel operating the valves for that end of the furnace. Likewise, the action of the other set of contacts on the recorder is controlled by a thermocouple in the soaking or finishing end of the furnace. This set operates the panel and valves for that end of the furnace. The recorder is an ordinary two-point continuous curve machine. The contacts on the recorder are adjustable so that any desired temperature can be maintained in either end of the furnace. The furnaces are gas-fired. The thermocouples extend 18 inches into the furnace, and as the tip of each is only a couple inches above the steel, the temperature of the steel affects them very quickly. The operation of the valves is such that there is always a small amount of gas flowing into the burner manifolds; but the desired temperatures are maintained by the length of the periods the valves stay open to maximum and the frequency with which they are opened. As it requires electric current to keep the valves open to maximum, in case of a breakdown in the power circuit the furnaces cool down to about 1200 degrees Fahr. instead of overheating. The maximum and minimum openings of the valves are also adjustable.

Fig. 19 shows the unloading end of an endless conveyor type of furnace used to draw the temper of the quenched plates. It takes about half an hour to pass through the heated zone which is at a temperature of about 900 degrees Fahr. There are still two or three large factories using salt baths instead of these furnaces for drawing.

As the plates come from the draw fires, they are tested for Brinell hardness. This should be between 350 and 418 on carbon steel, and 364 and 430 on alloy steel. As stated before, the heat treatment is also checked frequently through microsections of the coupons which accompany production through these furnaces.

While the plates are still hot from the draw fires, they are fitted, if necessary, so that each plate will bear evenly on the one next to it. The loose plates, still in the order they are found in the completed spring, now pass onto the conveyor where they are buffed, doped (greased), fitted with clips and bushings, and bolted together. They are then given the capacity test on a testing machine such as is shown in Fig. 20. When the upper dial indicates the specified load, the lower dial must indicate the required deflection. Another important test in the final inspection is for the parallelism of eyes.

In the days gone by we used a horse and carriage, but today we go at the speed of a railway train over roads that are not always as level as the rails over which the train passes. It is necessary, therefore, that the chassis springs of the modern automobile be made so that they will hold up for millions of vibrations under this rough treatment on the road.

While this paper has covered only in a brief way the manufacture of leaf springs it has endeavored to show the various steps required in the routine production of these components. The necessity for close inspection is paramount in obtaining rapid production through the shop, interchangeability in assembly and maximum life while in service.

EVIDENCES OF A CARBON-IRON EUTECTOID AND RESULTING MODIFICATION OF THE EQUILIBRIUM DIAGRAM

By Anson Hayes and W. J. Diederichs

Abstract

As indicated in the title of this paper the authors have correlated data which has been obtained recently partly by the present authors and partly by other investigators.

This paper points out that the abrupt change in the direction of the curve at 760 degrees Cent. (1400 degrees Fahr.) marks the completion of the absorption of heat due to the Ac_2 *change. The second absorption which reaches a maximum at 800 degrees Cent. (1470 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon, and is therefore the carbon-iron eutectoid point on heating. The absence of an* Ac_1 *change is accounted for by the practical absence of combined carbon in completely malleablized iron.*

THE writers have recently published a paper[1] presenting a theory for the mechanism of graphitization of white cast iron and high carbon steels. This theory, insofar as it referred to the completion of graphitization, was based upon the assumption that there existed a carbon-iron eutectoid. One of the purposes of this paper is to present considerable additional evidence which has more recently come to our attention.

In our previous paper, we reasoned from the evidence presented that there was a carbon-iron eutectoid located at the intersection of the carbon solubility line with the lines A_2 or A_{2-3}, and that this intersection was located at approximately 800 degrees Cent. (1472 degrees Fahr.)

The authors had planned a rather elaborate series of experiments to either prove or disprove the presence of this eutectoid. A considerable portion of this program was made unnecessary by the appearance of a paper by H. A. Schwartz[2] and co-workers. They present experimental data on white and malleable cast iron consisting of cooling curves, solubility of carbon under equilibrium conditions obtained both from white and malleable iron, and specific resistances of malleable iron reheated to various temperatures and quenched.

Fig. 1 is a reproduction of their cooling curve data. They state that this figure represents both heating and cooling curves on completely malleableized iron on initial and subsequent heating cycles.

The initial heating curve seems to show a heat evolution on heating. Such action, however, is contrary to the known action of equilibrium systems. Since the conditions that prevail in the process of manufacturing malleable iron must be admitted to be such as to approach those required to attain equilibrium conditions, a conclusion that such a heat evolution during this heating had occurred is untenable. Realizing the above difficulties, heating

1. TRANSACTIONS of American Society for Steel Treating, March, 1923.
2. *Transactions* of the Institute of Mining and Metallurgical Engineers, No. 1181S, August, 1922.

A paper written by Dr. Anson Hayes and W. J. Diederichs. Of the authors, Dr. Hayes is associate professor of physical chemistry and metallography and Mr. Diederichs is associate professor of mechanical engineering, Iowa State College, Ames, Iowa.

and cooling curves were repeated in this laboratory. The curves obtained duplicated those presented by Schwartz.

At this point we wish to call attention to a statement due to G. K. Burgess and J. J. Crowe[3] in discussing the forms of cooling curves. They state—"an examination of some of the heating curves will perhaps give the erroneous impression that Ac_2 is an evolution rather than an absorption of heat. The swingback at the maximum is very abrupt, following what appears to be a gradual building up of this maximum from an indeterminate low temperature." In view of these facts the initial heating

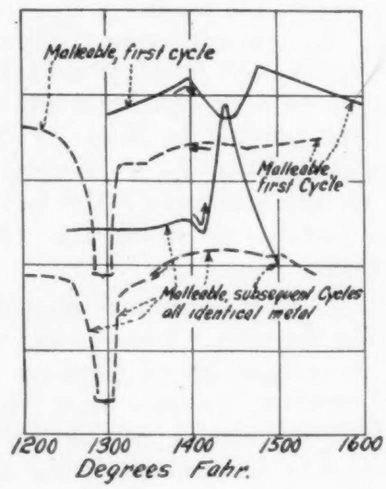

Fig. 1—Thermal Critical Points of Malleable Iron. (Schwartz.)

curve shown may be interpreted as follows: The abrupt change in the direction of the curve at 760 degrees Cent. (1400 degrees Fahr.) marks the completion of the absorption of heat due to the Ac_2 change. There is a marked swingback immediately after this change is completed. The second absorption which reaches a maximum at 800 degrees Cent. (1470 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon, and is therefore the carbon-iron eutectoid point on heating. The absence of an Ac_1 change is accounted for by the practical absence of combined carbon in completely malleablized iron.

The work of Howard Scott[4], "the Magnetic Change A_2 in Silicon and Chromium Steels," appeared at an opportune time to substantiate the above interpretation. He shows that Ac_2 is lowered at the rate of 21 degrees Cent., (70 degrees Fahr.) and that Ac_1 is raised 21 degrees Cent. (70 degrees Fahr.) for each per cent of silicon. He also shows that Ar_1 is raised at the rate of 18 degrees Cent., (64 degrees Fahr.) For an iron containing 1.2 per cent silicon the Ac_2 point (and therefore probably the Ar_2 point also, since the A_2 point occurs at the same temperature on heating and cooling) will occur at 758 degrees Cent. (1397 degrees Fahr.) This is in excellent agreement with the interpretations just given to the heating curve, since Schwartz reports this malleable iron as containing 1.26 per cent of silicon. Our interpretation placed the Ac_2

3. **Critical Ranges A_2 and A_3 of Pure Iron; Bulletin of Bureau of Standards, Vol. 10, No. 3, page 365.**

4. ***Chemical and Metallurgical Engineering*, January 31, 1923.**

point at 760 degrees Cent. (1400 degrees Fahr.) and in the light of Scott's work it should have appeared at 759 degrees Cent. (1397 degrees Fahr.).

Before attempting to interpret the initial cooling curve the following facts should be kept clearly in mind:

1. It can be assumed that the Ac_2 and Ar_2 points occur at identical temperatures since this is a characteristic of the A_2 transformation in steels.

2. In this particular cast iron, since silicon is 1.26 per cent, Ar_2 is at 759 degrees Cent. (1397 degrees Fahr.), according to the work of Scott.

3. The A_1 lags on either heating or cooling, and may therefore occur above A_2 on heating and below A_2 on cooling, depending upon the rate of temperature change.

4. Upon the initial heating of a completely malleablized iron preparatory to running a cooling curve, carbon goes into solid solution to approximately 0.6 per cent, the exact percentage depending somewhat upon the temperature to which the specimen is carried.

In discussing the initial cooling curve, it should be noted that there is no Ar_2 point evident at 760 degrees Cent. (1400 degrees Fahr.) as might be expected. It is to be remembered that as carbon concentration increases the Beta transformation merges with the A_1 transformation and is no longer evident. The occurence of 0.6 per cent carbon in solution, as in this instance, gives rise to the condition that only a small portion of Beta iron, if any, is formed prior to the merging of A_2 and A_1, and therefore the A_2 transformation is not evident.

The slight evolution of heat shown at 735 degrees Cent. (1350 degrees Fahr.) is due to the separation of Alpha iron. This separation continues until the solid solution composition attains that of the cementite eutectoid, at which time the temperature has fallen to 715 degrees Cent. (1320 degrees Fahr.). Here the formation of pearlite results in the pronounced heat evolution shown.

On the second heating the Ac_2 transformation is again apparent at 760 degrees Cent. (1400 degrees Fahr.), followed by the swingback mentioned previously. This swingback is cut short by the large heat absorption incident to the absorption of pearlite (or the Ac_1 transformation). The pearlite is that which was formed on the initial heating and which failed to graphitize on cooling. The location of Ac_1 above Ac_2 in this case is an instance of the lagging action previously mentioned. The lack of an evident heat absorption due to the iron carbon eutectoid on this second heating is probably due to its being completely masked by the absorption due to pearlite, and more particularly due to the fact that only a small amount of carbon and Beta iron enter solution at this point on the second heating. Subsequent heatings and coolings from this stage are simply repetitions of these actions.

The facts presented in the above discussion of the initial heating curve indicates that the iron-carbon eutectoid is in the neighborhood of 800 degrees Cent. (1470 degrees Fahr.). Since the rate of heating used in determining this curve and the tendency of the iron-carbon eutectoid transition to lag is not known, these data allow only an approximate

location of the eutectoid. The data presented in the following tables indicate that the iron-carbon eutectoid does lag and that it really lies somewhat lower than 800 degrees Cent. (1470 degrees Fahr.)

Table 1 (a and b), taken from the paper of Schwartz and co-workers, contains the data on the solubility of carbon in iron obtained under conditions which should produce equilibrium. Table 1 (a) represents the percentage of combined carbon present in a white iron sample heated to the temperature shown for periods ranging from 100

Table I

Solubility of Carbon in the Stable System
(From Schwartz)

(a) Beginning with hard iron

Temperature Degrees Centigrade	Per cent. Combined Carbon	Decrease in Combined Carbon Per Cent	During last hours
740	0.08	0.00	144
750	0.12	0.00	72
775	0.57	0.09	96
790	0.78	0.04	96
790	0.66	0.05	96
825	0.68	—0.02	96
840	0.81	—0.02	96
850	0.73	0.01	72
950	1.10	Same time as 850 degrees Cent. equilibrium, graphite burned down to 0.12 per cent	

(b) Beginning with Annealed Iron

Temperature Degrees Centigrade	Per Cent Combined Carbon	Increase in Combined Carbon Per Cent	During last hours
740	0.05	—0.05	4
750	0.03	—0.04	4
780	0.56	0.27	5
1100	1.75	0.06	½
		Graphite exhausted to 0.01 per cent	

to 300 hours. As a criterion of the attainment of equilibrium a check specimen was held at temperature for about 100 hours additional. Graphitization was initiated at temperatures of 900 to 1000 degrees Cent. (1652 to 1832 degrees Fahr.) in each case. Table 1 (b) represents the percentage of combined carbon present in a malleable iron sample which has been brought to the temperature shown and held at temperatures for the times shown. A check specimen was also used in this case. The values in both (a) and (b) of Table 1 undoubtedly represent equilibrium values, within the limits of accuracy of the methods used in determining combined carbon. We call attention to a variation of 0.12 per cent carbon on identical specimens treated at 790 degrees Cent.

It is to be noted that in Table I (a) there is a sharp decrease in combined carbon from 775 to 750 degrees Cent. (1427 to 1382 degrees Fahr.). In Table I (b) there is the same order of increase of combined carbon between 750 and 780 degrees Cent. (1382 and 1436 degrees Fahr.). It is to be noted that holding a specimen of malleable at any temperature below 750 degrees Cent. (1382 degrees Fahr.) does not cause a formation of Fe_3C, but that at a temperature lying between 750 and 780 degrees Cent. (1382 and 1436 degrees Fahr.) the combination of carbon and iron occurs abruptly. In like manner, it is noted that holding white iron at a temperature above 780 degrees Cent. (1436 degrees Fahr.) leaves at least as much as 0.56 per cent carbon in the combined form. At some temperature between 780 and 750 degrees

Cent. (1436 and 1382 degrees Fahr.) graphitization becomes practically complete. This evidence indicates very strongly the existence of a carbon-iron eutectoid at some point within this temperature interval corresponding to a carbon solubility content which is 0.56 per cent plus or minus the error of the carbon determination. It is to be regretted that such wide temperature intervals in this particularly interesting range were used.

We present further, Fig. 2, also taken from the paper already cited. They state—"if a completely graphitized specimen is heated to successively higher temperatures and cooled fairly rapidly after each

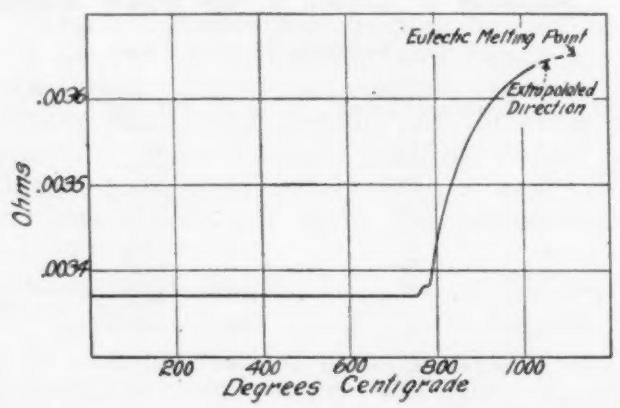

Fig. 2—Resistance at 22 Degrees Cent. of Malleable Iron After Cooling Rapidly from Various Temperatures. (Schwartz)

heating, the Ac_1 (stable) point should be indicated by a permanent change in resistance." Fig. 2 plots the results of such an experiment. Since nothing definite is known as to the rates of heating and cooling, or the length of time held at heat, we would only call attention to the fact that a rapid change in the electrical resistance occurs between 760 and 780 degrees Cent. (1400 and 1436 degrees Fahr.). This again suggests a carbon-iron eutectoid located somewhere between these temperature ranges. Due to our noting the uncertainty of some 30 degrees Cent., and some 0.2 per cent carbon in the location of the iron-carbon eutectoid according to the data presented, an investigation to accurately determine its location was undertaken in this laboratory by Messrs. H. E. Flanders and E. E. Moore. The results of this investigation will be ready for publication soon.

In addition, we wish to refer to the well known paper, "The Range of Solidification and the Critical Ranges of Iron Carbon Alloys," by Carpenter and Keeling[5]. The constitutional diagram resulting from their work is shown in Fig. 3. No interpretation of the significance of the points ranging across the diagram at temperatures of 775 to 800 degrees Cent. (1427 to 1472 degrees Fahr.) has to our knowledge ever been made. It is strongly suggested that the heat effects noted were due to the initiation of separation of Beta iron at the iron-carbon eutectoid, with or without the simultaneous separation of graphite. This series of points should not be confused with the Beta iron transformation occurring at the temperature A_2. It is to be noted in Fig. 3 that there is a sharp break of some 25 degrees Cent. in the temperature at which

5. *Journal* of the Iron and Steel Institute (British), No. 1, 1904.

these heat effects are noted between a carbon concentration of 0.4 and 0.6 per cent.

Carpenter and Keeling state that in obtaining their cooling curves the specimens were treated as follows: They were heated to a high temperature approaching that of incipient fusion in about 1½ hours, were there held for approximately ½ hour and were then cooled to 500 degrees Cent. (932 degrees Fahr.). This required an additional time of 1 hour and 20 minutes. To our knowledge no one has presented data as to the rate of graphitization at high temperature of *pure* iron car-

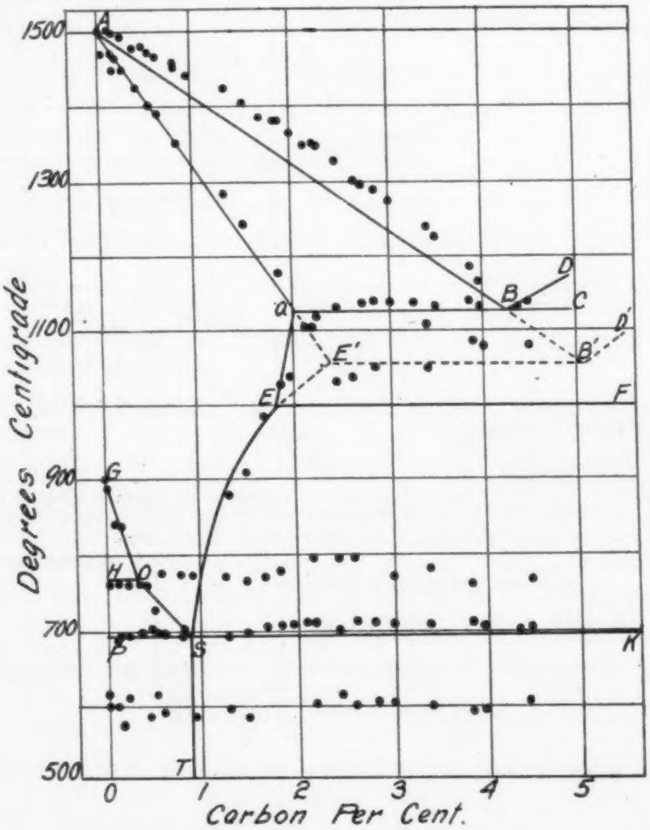

Fig. 3—Carpenter and Keeling's Diagram. (Sauveur.)

bon alloys such as here used. It is known, however, that white cast iron, as well as commercial high carbon steels, when cooled from high temperatures in small laboratory furnaces which reduce the temperature to below the critical in 1½ to 2 hours, results in typical bull's-eye structure; i. e., in partial graphitization at or near the eutectoid point.

The fact that this series of points ranges across the diagram at a temperature so distinctly above that of the Beta transformation that it suggests the presence of an iron-carbon eutectoid at this temperature. This would place the eutectoid at approximately 780 degrees Cent. (1436 degrees Fahr.) in pure iron carbon alloys. Having no knowledge of the effects of alloying constituents on the location of the iron-carbon eutectoid, we refrain from drawing any conclusions from the close agreement between its location in white iron and Carpenter and Keeling's specimens which were of considerable purity. We wish to point out here that attributing the heat effects noted by Carpenter and Keeling at 800

degrees Cent. (1472 degrees Fahr.) to the presence of a carbon-iron eutectoid demands very much more rapid rates of graphitization in these purer iron-carbon alloys than are encountered in the graphitization of white iron, since Carpenter and Keeling used such rapid cooling rates.

It seems probable, in the light of this reasoning, that a specimen of any carbon content, if cooled slowly from a high temperature to the temperature of the carbon-iron eutectoid and there held while sufficient heat was extracted, would completely graphitize. The evidence seems

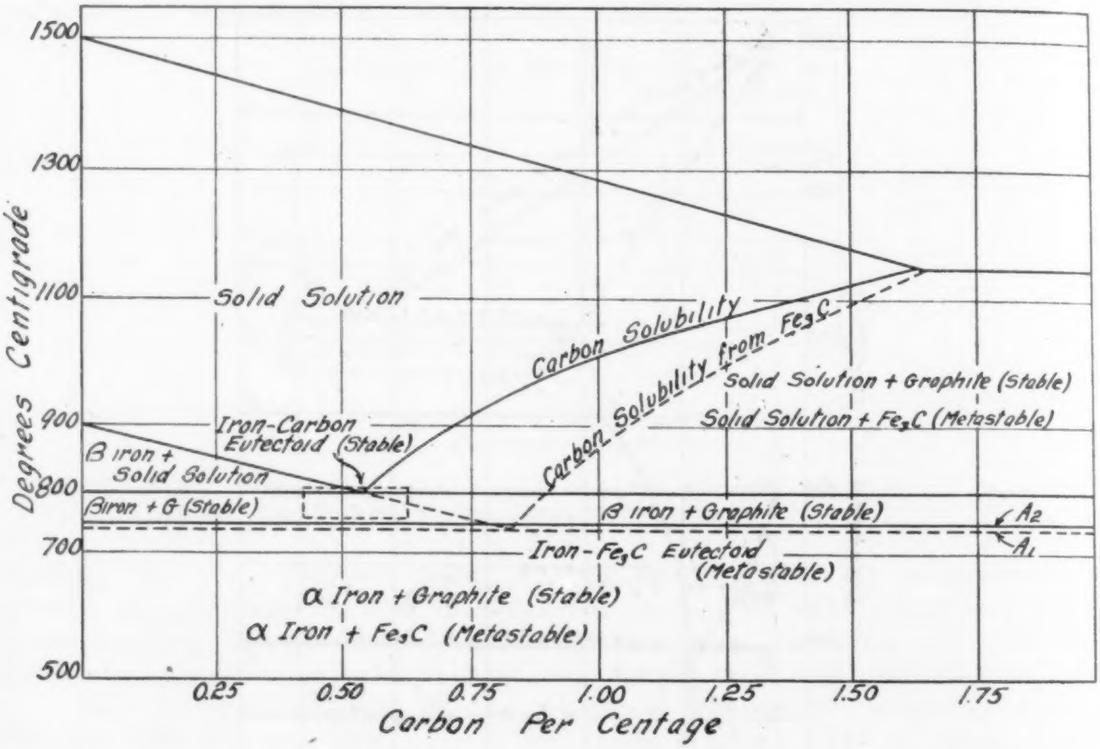

Fig. 4—Equilibrium Diagram for Iron-Carbon Alloys of Commercial White Cast Iron Composition.

to indicate that partial graphitization is actually taking place in specimens of 0.6 per cent carbon or more. That partial graphitization also took place in specimens of lower than 0.6 per cent carbon concentration, but that the heat effect was masked by the close proximity of the A_2 change, is also possible. The heat effect would, of course, be less intense as the carbon taking part in the action became less. It is to be expected that graphitization of steels above 0.6 per cent carbon would take place more readily since the stable form of carbon would be present to act as a seeding agent at the time the eutectoid was reached.

The location of the iron-carbon eutectoid in pure alloys, together with the rates of graphitization in these alloys, is now being made the subject of an extensive investigation by Waite P. Fishel in these laboratories.

The preceding discussion naturally leads to a conception of the equilibrium diagram for compositions ordinarily used in white cast iron as shown in Fig. 4. The conditions of stable equilibrium are indicated by the solid lines; those for metastable equilibrium are shown

by broken lines. The uncertainty in the location of the iron-carbon eutectoid is shown by the rectangle which surrounds it. The fields and lines on the diagram are fully labelled and are self-explanatory.

It was pointed out in our previous paper that in case there was but one solid solution; namely, that of carbon in Gamma iron, the iron-carbon eutectoid must be located at the intersection of the carbon solubility line with the A_3 or the A_{2-3} lines. The results of X-ray work seem to establish beyond doubt that there is but the one solid solution. We, accordingly, have located the iron-carbon eutectoid within the rectangle as shown; i. e., within the range of 780 to 800 degrees Cent. (1432 to 1472 degrees Fahr.) for temperature, and at approximately 0.56 per cent carbon.

It has been the idea of the writers that the behavior of cast iron and steel will be found to be fundamentally the same, though many theoretical discussions which have appeared would lead one to believe otherwise. It is expected that work now in progress in this laboratory, to which we have already referred, will justify the presentation of an equilibrium diagram for steel which will be very similar to this one.

Discussion of Paper By H. A. Schwartz

The explanation by Hayes and Diederichs of the peak of 760 degrees Cent. (1400 degrees Fahr.) as being A_2 depressed below A_1 is, in the writer's opinion correct. Data more recently obtained in this laboratory on alloys of intermediate compositions seem to have yielded a progressive series of figures connecting known A_2 points with this point. Magnetometric investigations would be desirable, but would probably confirm the conclusion reached by the authors.

The writer, is, however, not in agreement with the interpretation of his own data placing Ac_1 at 800 degrees Cent. (1472 degrees Fahr.). This is the termination of the reaction which began at the break in temperature at just under 1450 degrees Fahr., say 785 degrees Cent., where resolution of carbon began. This is confirmed by the authors' Fig. 2 (Fig. 4 of our publication) showing a permanent resistance change at 760 to 775 degrees Cent., (1400 to 1427 degrees Fahr.). The use of the break in a differential temperature curve as defining the location of the critical point is in conformity with the views of Dr. H. M. Howe.

The discrepancy between the fourth and fifth results in Table I (a) is not, as Hayes and Diederichs believe, a lack of agreement between results under identical experimental conditions. In both cases the reaction is still proceeding at the rate of 0.04 and 0.05 per cent graphite in the last 96 hours. This was assumed to mark the completion of the reaction in line 4. Since the result was apparently erratic, the experiment was repeated using a longer time with the result shown in line 5.

It has been pointed out by Howe[1] that under the circumstances of the experiment the lowest trustworthy value of "combined" carbon marks the best approximation of the solubility. The above explanation might have been included in the writer's original publication, but was

1. *Transactions* of the American Institute of Mechanical Engineers. Vol. XXXIX, page 37.

omitted in the interests of brevity. It is here included since it may apparently be a source of confusion.

The analytical precision of our combined carbon data is probably better than 0.05 per cent; perhaps 0.02 per cent, and the true values of combined carbon can not be higher than the correct analytical values.

The assumption that the A_{tm} line and the A_1 stable line intersect on the usual A_{2-3} is based on the assumption that the A_{2-3} line is the same in both systems. However, plausible this postulate may be, we can not accept it unproven. Work is approaching completion under the writer's supervision calculated to cast light upon this point. For the present it will suffice to point out that Guillet and Portevin[2] recognize a possible difference.

Since the publicaton of our data we have read the earlier work of Ruer[3] which confirms our conclusions regarding the approximate spread between A_1 stable and metastable, and shows a much smaller divergence than that assumed by Hayes and Diederichs in their Fig. 4.

Authors' Reply to Mr. Schwartz's Discussion

The authors note that Mr. Schwartz agrees with their interpretation of the thermal data as it affects the A_2 and A_1 points.

In regard to the exact location of the A_1 point on heating, the authors have no reason to take issue with Mr. Schwartz. In speaking of this point we use the following expression: "There is a marked swingback immediately after this (Ac_2) change is completed. The second absorption which reaches *a maximum* at 800 degrees Cent. (1472 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon and is, therefore, the carbon-iron eutectoid."

We wish to state that we recognize in this statement that the absorption of heat due to the iron-carbon eutectoid set in at some lower temperature than 800 degrees Cent. (1472 degrees Fahr.) In making the statement "—and is, therefore, the carbon-iron eutectoid on heating," the authors' intent was to identify the iron-carbon eutectoid with the break in this heating curve, and not to give the impression that this was the temperature of the carbon-iron eutectoid. Further on in the paper we state "The data presented in the following tables indicate that the iron-carbon eutectoid does lag and that it really lies somewhat lower than 800 degrees Cent." It was due to lack of sufficiently definite information in regard both to the temperature and the carbon content of the solid solution in equilibrium at the carbon-iron eutectoid that the authors inserted the broken line rectangle in their diagram. This rectangle shows its location is indefinite by some 40 degrees Cent. In the light of Mr. Schwartz's explanation of his analytical data, it would now seem that the uncertainty regarding the carbon content of the eutectoid solid solution as shown by the rectangle is larger than need be.

In regard to the carbon-iron eutectoid being located at the intersection of the carbon solubility and the usual A_{2-3} lines, we wish to point out that all the phenomena noted, upon which we have data, can be explained without the assumption of two distinct solid solutions. There are numerous examples in liquid solutions where all the data indicates that the form of the solute as it exists in the solution, either

2. Metallography and Macrography, Fig. 218.
3. *Zeit. Anorg. Chem.*, 117-4, page 249.

from metastable forms or from stable forms, is identical, differing only in the fact that the concentration corresponding to saturated solution from the metastable form is greater than the concentration of that derived from the stable form. In the case under discussion the metastable form (Fe_3C) also causes higher concentrations.

We wish to thank Mr. Schwartz for calling our attention to Ruer's article. After a careful study of this paper we feel that considerable additional experimental data will be required to justify Ruer's conclusion that the second break in his heating curves represents the iron-carbon eutectoid. It seems very possible to the writers that this second break marks the completion of absorbtion of alpha iron.

We would point out further that Ruer's data was obtained from pure iron-carbon alloys and that our work deals with white iron compositions. It is possible that in the two types of metal corresponding points do not agree.

METALLURGY IN THE MODERN SHOP

By M. H. Medwedeff

THE term metallurgy in its broad significance relates to the fundamental and accumulated knowledge dealing with the manufacture and fabrication of metals. In the case of steel, we might start with the reduction of the iron from its ores, the refining of the iron with its subsequent conversion into steel by various processes including the Bessemer, the open-hearth, the crucible or electric furnace methods; and finally its fabrication into billets, bars, rods, plates, etc., which are the raw materials with which the user of steel begins in the manufacture of his product, be it machinery, tools, automobile parts or the innumerable products of which steel forms an important part.

In this era of specialization, the practice of metallurgy seems to be divided into two distinct fields; that as applied to the manufacture of metal, and that as applied in their industrial uses, of fabrication in finished or semi-finished products. The manufacturing metallurgist deals with studying melting practices, developing formulas for the composition of his metals or solving difficulties arising in the mill, such as production of sound steel, splitting of billets in the blooming mill, etc. The metallurgist in the service of the consumer deals with the problems arising in the uses of these materials. We will confine these remarks to the latter field and particularly to steel, the metal in which most of us are interested.

Metallurgy in the shop deals with the physical conditions of metals and their behavior under the varying conditions of mechanical working, hot or cold, such as forging, punching, pressing, machining and heat treating. The master mechanic or "the man at the fire", may truly be experts in their lines, the first, having complete knowledge and experience in the design and operation of machines or production methods, the second with an experienced hand and eye in successfully heat treating a routine product or tools of well known "brands of steel". But when things go wrong in production processes, resulting in a sudden slackening in production or increased spoilage of work, due to causes mystifying to the mechanical department, a metallurgical investigation may easily locate the trouble. The investigation may disclose the fact that the material is too hard to machine under normal operating conditions of the equipment. The metallurgist may recommend that changes be made in the processing of the steel to put it into the physical condition suitable for the respective operating conditions, but where conditions permit it may be necessary to change cutting speeds. The changing of machine-tool speeds, however, affects very materially the production of a shop. Metallurgists are not always taken into the confidence of the designing engineer, and frequently materials are specified for manufacturing parts, while being suitable, yet may prove to cause manufacturing difficulties. An example of this might be the use of very low carbon steel for parts requiring considerable machining, resulting in the tearing of the work and the necessity for frequent regrinding of tools. In this case it becomes necessary to change the material. Or again a material is specified for cold working operations, such as punch pressing, and it is found that considerable cracking occurs due to the steel being too high in carbon. These points are given as examples to illustrate the application of metallurgy to practice.

A paper presented before a meeting of the Society. The author M. H. Medwedeff is chemist and metallurgist with the Wyoming Shovel Works, Wyoming, Pa.

Familiarity With Shop Practice Essential

The efficient metallurgist should be familiar with shop practice. He need not concern himself with the arrangement of machinery and mechanical details, but he should be familiar with performance of tools and cutting speeds. This would enable him to render effective service in machining difficulties or spoilage of cutting tools. This is of special importance in new organizations with new equipment where in spite of expert operating personell troubles arise which only the application of sound metallurgical knowledge can overcome. The writer has in mind an instance, an installation of trimming machines, where a grade of steel was selected, which was entirely unsuited for the operating conditions, and resulted in frequent failure of tools and otherwise spoiling the work. The steel salesman, who is seldom a metallurgist, when called upon in this case, was perforce, biased and was inclined to place the blame on conditions other than the fitness of the steel he furnished for this particular job. Somehow concerns employing metallurgists, either in their laboratories or as active heads of their heat treating departments, do not look to them for such service. It is up to the metallurgist to make his presence felt by unobtrusively working himself into such service so that the operating department will come to him for help on all such occasions.

We have spoken so far of metallurgical service in an advisory capacity, as an active aid to the man at the machine. It seeks to correct operating troubles due to physical conditions of the material used or the tools employed. Metallurgical service is however applied directly in processing the finished or unfinished steel products. Metallurgical knowledge dictates the annealing temperatures for the raw product, or the hardening and tempering temperatures for the finished or semifinished product.

The "man at the fire" may indeed be a skilled workman and successfully harden intricately designed tools or parts. But when things go wrong with the "man at the fire", and they often do, it is the man with the knowledge of "calescence, pearlite, cementite and pyrometers, etc.' who comes to the rescue. In the years past, small account was taken of the spoilage in the heat-treating shop, it was considered a part of the days work and usually the steel was blamed. Today scientific knowledge lends its aid to the practical heat treater in minimizing spoilage. Scientific control seeks to prevent the errors of "the man at the fire". The practical heat treater has obtained wonderful results considering his lack of fundamental knowledge dealing with the properties of steel. The intelligent worker, however, is today anxious to make up this defect by burning the midnight oil and studying the very excellent books available on the subject of the heat treatment of steel. He has become much interested in the story the microscope tells when he strikes a snag, and in proportion to his interest in fundamental knowledge, his suspicion of the man with the knowledge of "calescence" diminishes and he becomes a genuine asset.

Metallurgy seeks to cooperate with the designing engineer in working out the most suitable materials for the design of the parts of his machine. The engineer calculates the strength that operating conditions will demand of the individual parts of the machine he is developing, and the metallurgist works out the physical properties of these materials and imparts to them the strength that engineering practice demands.

A Study of Typical Failures Important

Perhaps the greatest service the metallurgist renders is in the study

of periodic or chronic failures of parts in service. A study of failures in service of automobile parts furnishes us an excellent example because the automobile embraces most of the important uses of steel under the most varied conditions. In studying these failures we are thus enabled to apply rational cures and avoid the recurrence of such failures. This is of particular importance in developing a new machine. Experimental trials may develop chronic failure, in a particular part. As an example we will take a particular case, that of repeated failures of crankshafts which failed at nearly the same place each time. The failure may have been due to either faulty design, bad workmanship, faulty heat treatment or the selection of the wrong material for the service requirements of this part. Just a little thought will dismiss the possibility of faulty heat treatment, as it is not likely that failure would occur in the same place, even if this should have been the cause of failure. Examination of the fractured surface showed that the heat treatment had been uniform and the physical tests revealed the desired physical properties. The workmanship of the part itself as nearly perfect as commercial practice permits. We then have two considerations left, either faulty design or the selection of the wrong material for the part. A study of the fracture throws considerable light on the subject. If the fracture is smooth over the greater portion of its area, showing concentric rings, and the steel is rougher over one portion than over the rest of it, it indicates a typical fatigue failure. Failure in these pieces occured as a result of either a large number of stresses applied intermittently in one direction or alternately in opposite directions. When strains are large and approach the elastic limit, failure is rapid, but when stresses are relatively small, failure is postponed indefinitely. However, it is not the purpose of this paper to enter into a discussion of the mechanism of fatigue failures. Having established that failure was due to fatigue of the steel we must now suggest a cure to prevent its occurrence. Obviously two remedies suggest themselves, we must either redesign the part and give it a larger cross section to withstand the load or raise the elastic limit so that while the stress is the same it will be considerably below the elastic limit. Our choice will be governed by practical shop considerations. The latter necessitates the selection of a higher grade material and is apt to increase manufacturing costs due to slowing up in machining operation. If conditions permit, the design of the part is usually changed.

Sometimes parts fail due entirely to faulty design in not taking into consideration metallurgical details. As an illustration of this we might mention failures in steering-knuckles. These sometimes fail at the junction of the vertical member with the spindle. This is frequently due to an insufficient fillet. Sometimes these are due to improper material or again to improper specification of physical properties for the part.

One can go on indefinitely and enumerate investigation and studies of failures and their remedies, based on co-ordinating highly developed metallurgical knowledge with sound engineering practice. These few cases have been mentioned, not as a plea for the metallurgist in the shop, but for the larger use and appreciation of the potentialities of metallurgical service, and if these remarks serve their purpose, the writer will have been well repaid.

DELAYED CRYSTALLIZATION IN THE CARBON STEELS—THE FORMATION OF PEARLITE, TROOSTITE, AND MARTENSITE

By A. F. Hallimond

Abstract

The paper deals with the application of the supersaturation theory of steel. A summary of recent researches on delayed crystallization and inoculation is first given, after which the origin of pearlite, troostite, and martensite is discussed. The area below the eutectoid point, common to the metastable ranges for cementite and ferrite, is termed the eutectoid area, and indicates those conditions under which the growth of pearlite can occur. The causes that determine the spacing of pearlite are described. Martensite is regarded as a labile shower of a-ferrite and troostite as a labile shower of cementite; in the latter case the appearance of the cementite is quickly followed by the growth of a-ferrite due to inoculation by the cementite at a relatively high temperature.

THE equilibrium relations of ferrite, cementite, and austenite present, as is well known, a close analogy with those of two mutually insoluble solids crystallizing from a liquid solution. This analogy has provided a convenient basis for the description of the microstructures exhibited by those constituents in slowly cooled steels. Of recent years, however, the active prosecution of research on quenching has rendered it necessary to discuss the growth of structures, such as martensite and troosite, that have no counterpart among those formed by crystallization from a liquid under approximately reversible or "equilibrium" conditions. In such cases it is necessary to take into account the principles governing "delayed crystallization"; these have been established chiefly as the result of a series of researches by Miers, Barker, and other workers during the last twenty years, and have not yet had time to receive full treatment in most text-books. The author has therefore ventured, before dealing with the carbon steels, to give in the first part of this paper a somewhat more detailed summary of that work than would otherwise have been necessary. In the second part an attempt has been made to indicate the lines on which these principles may be applied to account for the structures developed in carbon steels; the accurate thermal and other investigations required have recently been made available in the detailed researches of Portevin and others, and reference has been made to this work in discussing the delayed critical points and corresponding structures in terms of the supersaturation theory.

The view that the doubling of the critical points might be attributable to delayed crystallization is not new, for this was already suggested by Miers in 1907[3*] as a possible explanation of the doubled critical points observed by Roberts-Austen in certain alloys during solidification. Moreover, in the same paper, which deals with the freezing of a binary mixture, the conditions governing the appearance of crystals of each constituent are defined, and the

3* The small figures appearing after the names of authors or points of reference, refer to the bibliography appended to this paper.

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possible variations in the order of crystallization indicated. Again, of recent years, Stead, Portevin[26], and other workers have used the principle of inoculation by more or less "isomorphous" nuclei to account for the premature precipitation of cementite and the growth of ferrite in the neighborhood of inclusions. Finally Portevin[27] has given an outline of certain continental work on delayed crystallization, with reference to the devitrification of glasses, but this does not include any account of the English work above mentioned. No general application to the crystallization of steel has so far been given, and the present account has therefore been prepared in the hope of stimulating interest, and of providing material for the discussion of these questions. The development of a systematic treatment of this subject seems a necessary preliminary to the microstructural investigation of the special steels.

General Principles

In considering the influence of the rate of cooling upon microstructure, three main principles must be taken into account. The first concerns the existence, below the ordinary solubility curve for each constituent, of a range of temperature and concentration within which crystallization is only initiated upon the introduction of a suitable nucleus. The second is that the rate of growth of a crystal at first increases as the temperature falls below that of equilibrium, and then diminishes when a certain degree of supercooling is exceeded. The third is that the redistribution of heat and of dissolved matter, consequent on and essential to solidification at the surface of a growing crystal, is governed by gradients of temperature and concentration which depend in their turn upon the respective coefficients of heat conductivity and of diffusion.

Recent Researches on Delayed Crystallization and Inoculation

The Supersolubility Curve

The fact that many carefully supercooled solutions would only crystallize on the introduction of a nucleus has long been recognized.[11] Measurements by Tammann[12] indicated that the period of duration of this condition diminished as the temperature at which the solution was held fell below the normal saturation point, at which solid and liquid can permanently coexist. The tendency to crystallize* (like the crystallization-velocity) increased at first with diminishing temperature and then again diminshed, so that a fused substance cooled through ths range with sufficient speed remained as an amorphous solid, *i. e.*, a "glass." With moderate supercooling the nuclei appear rarely, or, as was shown by Miers[1] and Ostwald[11], not at all within a period of many weeks' duration. Ostwald proposed the terms *metastable* for this condition and *labile* for that induced by a greater degree of supercooling, in which crystallization, when once initiated, extends rapidly throughout the mass with the development of a characteristic shower of crystals. The metastable state was not at first regarded as being very sharply separated from the labile, but the sharpness of the boundary in certain cases was recognized by Ostwald.

As the result of extensive researches by Miers and his co-workers, the observation first recorded by him in 1906[1] has been fully verified in the case of numerous compounds and mixtures. It is possible, under suitable condi-

* Measured by the number of nuclei appearing in unit time in unit volume.

tions of experiment, to determine a sharply-defined boundary, termed the *supersaturation point,* between the metastable and the labile states, and a solution in a sealed tube may apparently persist indefinitely in the former condition, though a fall of a few degrees in temperature will at once cause the precipitation of the labile shower. Two standard methods are used in these researches: (*a*) The slow cooling of a liquid, covered if necessary with oil to prevent inoculation by dust in the air. At a well-defined temperature the substance in supersaturation crystallizes in numerous small crystals, termed the *labile shower.* With many liquids (*e. g.,* sodium chlorate solution) mechanical stirring is necessary before the shower will appear. The changes in concentration are measured by means of the refractive index, determined by total reflection in a glass prism immersed in the liquid[10]; when the shower appears the combined actions of the fall in concentration and the heat evolved cause a sharp diminution of the refractive index. (*b*) The second method consists in allowing the liquid to cool slowly in sealed glass tubes; with constant shaking many substances crystallize in a shower at the supersaturation point, but in certain cases it was necessary to place pieces of glass or heavy minerals such as corundum, garnets, etc., in the tube to increase the friction[1]; this was particularly the case with the more viscous liquids. The results of the two methods are concordant, and when the supersaturation points for various concentrations are plotted upon the ordinary freezing-point or solubility diagram for a mixture or solution they are found to lie on a second curve, termed the *supersolubility curve,* which lies below the ordinary equilibrium curve and follows a similar course, but is not necessarily strictly parallel to it. The space between the two curves represents the metastable state, that below the supersolubility curve, the labile state. A thin shower sometimes appears when a solution is shaken in the metastable state, owing probably to chance inoculation. If not shaken or stirred, the more viscous solution can be brought far into the labile state without the appearance of a shower.

The extent of the metastable range varies rather widely for different substances. For cæsium nitrate in aqueous solution it is practically zero[4], for ice forming in salt solutions it is usually 1 or 2 degrees Cent., while for $Na_2SO_3.7H_2O$ in aqueous solution it reaches 30 degrees Cent[8].

Miers indicates[3] the importance of these effects in determining structures. If the supersolubility curves of the two constituents are plotted on the diagram for a binary mixture having a eutectic point, the two curves intersect at a point termed the *hypereutectic point.* The conditions of crystallization in such a simple mixture were investigated for mixtures of salol with betol[3]; multiple critical points were observed in the neighborhood of the eutectic, and reference is made to the bearing of the experiments on the genesis of eutectic structures.

Following the same line of investigation a series of researches were made upon systems of which the components crystallized in a continuous series of mixed crystals[5], and in a series of mixed crystals forming a eutectic with the other constituent[9]. The supersolubility curves were determined and in some cases the composition of the first mixed crystals formed at the beginning of the labile shower was ascertained. These differed in composition from the liquid, even when the supersaturation point lay below the solidus curve. Viscosity must here play a considerable part, however, in limiting the selective crystallization of material, and the present observation does not seem essentially inconsistent with the observation of Day and Allen that the

viscous felspar melts, when crystallized below the solidus, yield crystals of the same composition as the liquid and not zoned.

The remaining references in this section relate to investigations, mainly on dissolved salts, in all of which satisfactory values for the supersolubility curve were obtained by the methods described above.

Inoculation

When the solution of a substance is in the metastable state, crystallization can be initiated at the surface of a suitable nucleus introduced from without or already present in the liquid. This nucleus must usually be a crystalline particle, either of the substance itself, or of an "isomorphous" body. The interpretation of the latter term has been much discussed, for detailed measurements show that, even in the case of crystals with close structural similarity, the actual dimensions of the space-lattice are characteristic for each substance; both angles and linear dimensions may vary widely within the same "isomorphous" group[32].

The nature of isomorphism and the conditions for parallel growth between different members of certain isomorphous series have been investigated by Barker[13, 16, 18]. The method of experiment was extremely simple, a drop of solution of one salt being placed on a fresh cleavage or other surface of the crystal on which parallel growth might be expected to occur. Three types of growth were recorded: (1) *Zonal growth,* by the deposition of a uniform crystalline layer over the whole surface of the inoculating crystal. (2) *Parallel growth,* by the deposition of many small separate crystals in parallel position, scattered over the surface of the inoculating crystal. (3) *Irregular growth* of many small separate crystals on the surface of the inoculating body, but not in parallel position. The first is limited to pairs of substances with very nearly identical molecular volume; the second occurs between the majority of isomorphous substances, while the third is found in those cases where the two crystals differ most widely in molecular volume. An idea of the degree of similarity necessary for parallel growth between halide salts of the alkali metals[16] may be formed from one of the extreme cases, in which RbBr, with a molecular volume of 49.30, yielded parallel growths on KCl which has the molecular volume 37.49.

The property of forming parallel growths is exhibited by many pairs of substances that are not capable of forming mixed crystals. It seems to be mainly dependent on the equality of molecular volume, or perhaps even on the equality of spacing in one or two directions only, for this would appear to be the determining factor in many cases of regular growth among minerals, in which crystals are arranged with such directions parallel.

As is well known, sodium nitrate crystallizes in parallel on the cleavage surface of a piece of calcite. This has been examined, with many other similar cases, by Barker[13], and also by Miers and Chevalier [14], and by Beilby [19]. In the metastable state the solution deposited parallel crystals, in the labile state the growth was irregular. The subject was taken up by Kreutz[21], who showed that sodium nitrate formed parallel growths on calcite and barytocalcite; lithium nitrate, on the other hand, would not make parallel growth on calcite, but readily did so on the isomorphous carbonates of manganese and iron. Comparison of the densities of these substances indicated again that similarity of volume is the chief factor and not similarity of crystal angles. A further interesting fact is observed by Barker[22], that calcite will always induce the precipitation of rhombohedral potassium nitrate, but that the crystals so formed are not in parallel position.

Chevalier[15] observed that different minerals, especially galena, induced crystallization in potash alum solutions at characteristic temperatures, while glass also acted as a nucleus, but only in the labile state.

In the light of the observations of Miers and Chevalier it seems legitimate to assume that in Barker's experiments the parallel growths represent, in the main, deposition from the metastable state and the irregular growths deposition from the labile state. We have, therefore, a range of conditions extending from a complete structural similarity that yields zonal growth as soon as the equilibrium curve is passed, to the non-isomorphous structures that usually only affect the solution when it has entered the labile state. For each foreign substance there will be a characteristic temperature at which it is capable of initiating crystal growth.

It has been recognized, by Miers and other workers with the same methods, that the determination of the supersaturation point may be affected by inoculation. The glass sides of the vessel, the surface of the liquid, and the platinum stirrer are all potential sources of inoculation, but it is shown that the point is but little affected by the conditions of experiment[1, 7]. The addition of mineral crystals to the tube experiments is apparently more dangerous, and Jones[4] considers that differences in the determined supersaturation points for ice are due to the use of garnets in the tubes. It is even possible for glass to induce parallel growth; thus a drop of potassium nitrate melted under a coverglass on a microscope slide crystallizes with a granular structure in which the principal axis of each grain is nearly perpendicular to the cover-glass. Sometimes scattered, irregularly orientated grains are seen, and it seems clear that crystallization has then begun at a few nuclei, while with a further drop in temperature the remainder of the nitrate solidified in parallel growth on the glass.

The Time Element.—Even in the production of a labile shower, the number of nuclei formed is finite, and it must be recognized that the occurrence at a given point of the necessary condition for spontaneous crystallization or for inoculation is dependent upon the lapse of time; the probable explanation of this lies in the occurrence of deviations from the average state of a fluid in the manner indicated by the kinetic theory. Nevertheless, the probability of crystallization in many cases increases so rapidly that with falling temperature that the labile shower has the appearance of being instantaneous, while even the formation of scattered crystals on an inoculating surface is subject to definite limits. In both cases, however, the number of nuclei can be diminished by sufficiently rapid cooling; thus sharply defined points are characteristic of rapidly crystallizing bodies, and in cases where crystallization is particularly slow, as in glasses, the supersaturation point is represented by a range of temperature in which the number of nuclei appearing undergoes a rapid increase[12]. On the whole there seems ground for regarding the true supersaturation or inoculation point as a definite limiting temperature, above which crystallization will not occur even on indefinitely slow cooling.

Application to Crystallization in Solid Bodies Such as Steel

In steel, crystallization takes place obviously in the complete absence of stirring, the only analogue of this being violent mechanical working of the sample. The transport of material and of heat by convection and the introduction of nuclei from outside are alike eliminated. The supersaturation point, which is often only developed on vigorous stirring in fluid solutions, is therefore not necessarily developed at all in steel, and it is not per-

missible at once to identify the point at which any particular recalescence begins with the supersaturation point of Miers. With relatively slow cooling we are much more likely to encounter the specific inoculation points characteristic of the various crystals present, and of the intergranular surfaces; in the steels now under discussion it is an almost invariable rule that the grains of a new constituent originate at surfaces and not in the body of the austenite. The criterion of the supersaturation point, if present, is the appearance of a shower of small crystals; in two cases only does this occur in steel, namely, on the formation of troostite and of martensite. The temperatures of formation of these constituents are therefore taken to represent the supersaturation points of austenite with reference to cementite and a-ferrite respectively, and the remaining recalescence points are regarded as originating in inoculation, at specific temperatures, by the surfaces from which the new constituents begin to grow.

Linear Crystallization-Velocity and Crystal-Habit

The speed with which a growing crystal-face advances normal to itself is termed the linear crystallization-velocity. When a solution is only very slightly supersaturated the rate of crystal-growth is small, and the habit of most crystals tends to be compact and symmetrical. It is under these conditions that the external form can accommodate itself to the condition that the surface energy shall be a minimum. When the degree of supersaturation is greater it would appear that growth is controlled by two factors; the diffusion of material into the approximately saturated layer in contact with the growing face, and also a definite heterogenous reaction-velocity conditioning the deposition of material. The latter would seem often to be the principal determining factor in the resulting crystallization-velocty; it may vary widely for different modifications of the same substance, as with tridymite and cristobalite, and for different faces of the same crystal. The result of the latter difference is that a crystal growing in a supersaturated solution often exhibits a tendency to growth in certain directions only, so that the normal crystal-habit gives place to pronounced acicular or tabular growth.

It was shown by Tammann[12] that this crystallization-velocity at first increases as the supercooling increases, then remains constant, and finally diminishes more or less sharply with falling temperature, probably owing in the first place to the usual increase in speed of a reaction with departure from equilibrium, and in the second place to the increase of viscosity and diminution of reaction-velocity with falling temperature. The subject has been summarized from the crystallographic standpoint by Ritzel[29] and, from the standpoint of glass-making, by Portevin[27].

Diffusion of Heat and of Material

The continued growth of a crystal is conditional on the maintenance of a supply of material by diffusion, and on the dissipation of the latent heat developed in crystallization. In the case of a pure substance the former effect does not come into account, and Tammann regarded the above-mentioned increase in rate of crystallization with supercooling as due simply to the second cause; the latent heat developed on crystallization sufficed to raise the temperature at the growing surface to a point near the true solubility curve, and further growth only proceeded as heat diffused away to the cooler parts of the solution.

Steel represents a somewhat extreme case, in which the heat conductivity

of the metal is great, while the coefficient of diffusion of carbon in γ-iron can hardly be regarded as more than that of a salt in water. Crystal growth will therefore take place under relatively isothermal conditions as regards the interior of the steel, the temperature of the surface of a growing constituent differing but little from that in the interior of the grains. Crystallization thus proceeds at any moment at the temperature recorded pyrometrically for the mass of the steel.

The transition from approximately equilibrium crystallization to a condition in which the structures begin to show very definite evidence of incomplete adjustment in concentration during the range Ar3-Ar1, occurs in the neighborhood of the critical rate of quenching, as determined by Portevin in his work on the delayed critical points[28]. That author records that at rates of cooling which yielded troosite the free constituents still separated in the noneutectoid steels. With faster quenching the austenite areas fail to contract with separation of the free constituent, and the whole sample is obtained in the martensitic state. In ordinary slow-cooled steels, therefore, it must be admitted that the readjustment of concentration has time to proceed nearly to equilibrium, and that the composition of the austenite areas does not vary to any great degree from the center to the margin.

The laws governing the diffusion of material are analogous with those governing the diffusion of heat. The development of temperature gradients in cooling solids has recently been discussed mathematically by Williamson and Adams[30], and the analogy between concentration-and temperature-gradients is referred to by Bowen[31]. Detailed reference to this question will not, however, be required here, and it will suffice to refer to these recent publications.

Crystallization in Ordinary Carbon Steels

An endeavor will next be made to ascertain how far the crystallization of the ordinary steels can be explained in terms of the supersaturation theory outlined in the preceding sections. Fig. 1 represents part of the usual iron-carbon diagram, *oa, ob* are the equilibrium curves for a-ferrite and cementite in contact with austenite; they meet in *o,* the eutectoid point, at a temperature of about 725 degrees Cent. Below these curves have been represented various lines required by the supersaturation theory. $o'a'$, $o'b'$ are the supersolubility curves below which martensite and, in part, troosite, are formed. The point o' is the hypereutectoid point (following the nomenclature of Miers[3]. The metastable range for a-ferrite lies between the lines *oa* and $o'a'$; that for cementite between the lines *ob* and $o'b'$. The areas below $o'a'$ and $o'b'$ are the labile regions for a-ferrite and cementite. In the area $opo'q$ both a-ferrite and cementite are metastable; in the presence of nuclei both constituents will grow simultaneously, and so this area represents those temperatures and concentrations at which eutectoid structure can develop. It will, therefore, be termed the *eutectoid area.* fF represents the inoculation line at which nuclei of a-ferrite appear on the intergranular surfaces of austenite. cC is similarly the line at which nuclei of cementite appear on the austenite surfaces. These indicate the points at which the free constituents first crystallize in cooling samples. The remaining two points represent the temperatures C′ at which cementite nuclei appear on the surface of free a-ferrite crystals, and F′ at which a-ferrite nuclei appear on the surface of free cementite crystals. These are the temperatures at which the eutectoid crystallization begins in hypo and hyper-eutectoid steels.

All the points of delayed crystallization, especially those of inoculation,

are depressed with increasing speed of cooling. The values given in the diagram correspond roughly with those for small samples about 16 millimeters in diameter, and have been based on the critical points given by Portevin and Garvin[28].

Crystallization on Slow Cooling: Pearlite

(*a*) *Hypoeutectoid Steels.*—Let a medium carbon steel d_1 (Fig. 1) cool slowly until the ferrite line is passed. In the absence of nuclei no free ferrite will appear till a point f_1 is reached at which inoculation occurs on the intergranular surfaces of the austenite. This occurs at a temperature far above that at which shower-precipitation takes place. The ferrite separates at the grain-boundaries† with recalescence (Ar3,2), and the remaining austenite has the composition *g*. With further cooling the ferrite grows and the austenite reaches the eutectoid composition *o*, but in the absence of nuclei no precipitation occurs and the concentration continues to increase until a point C′ is reached at which cementite appears by inoculation on the ferrite surfaces. The interior of the austenite inevitably lags somewhat in composition below the surface, and so the state of the austenite grains is best represented by a horizontal line C′1. This is within the eutectoid area, and growth of pearlite at once sets in with recalescence. Provided the rate of cooling is not too slow, the steel remains below the line *oc′* and continuous growth of grains of pearlite results. The temperature attained in the recalescence is from 690 to 700 degrees Cent., while the growth of pearlite originates at about 680 degrees Cent. This temperature is distinctly higher than the troostite recalescence point, and there is no reason to suppose that in slow cooling the margins of the austenite undergo a shower-precipitation, though this condition may be very nearly approached. In other words, the point C′ is within the metastable range and growth is initiated by inoculation.

(*b*) *Hypereutectoid Steels.*—Let steel d_2 (Fig. 1) cool slowly until the cementite line is passed. In the absence of nuclei precipitation will not begin until a point c_2 is reached at which free cementite grows by inoculation on the intergranular surfaces of the austenite. At this point the remaining austenite assumes the composition h_2 and, when the eutectoid temperature is reached, has the composition *o*. Ferrite does not appear until F′ is reached, at which *a*-ferrite appears at the cementite surfaces. Nuclei of both constituents being presented in the eutectoid area, growth of pearlite occurs with recalescence. The crystallization is initiated at about 665 to 675 degrees Cent., or at higher temperatures with slower cooling, and the recalescence point is about 710 degrees Cent. On account of the great steepness of the line *o*F′ the interior of the austenite has nearly eutectoid composition, and the temperature of eutectoid crystallization can consequently rise further toward the eutectoid point 725 degrees Cent., than in the hypoeutectoid steels.

(*c*) *Eutectoid Steels.*—It is clear that within a certain range of composition above and below the eutectoid point the austenite formed after separation of the free constituent will be at once in a condition for initiating the growth of pearlite at the points C′ and F′. Within this range there will be

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† The symmetry of a crystal forming a liquid is determined by the structure of the crystal, but in the case of a crystal forming at the expense of another crystalline solid there is no reason to expect the form to depend on one body rather than on the other. In steel, in fact, both α-ferrite and cementite develop "along the cleavage-planes of the austenite," and their shape is determined to a great extent by the symmetry of the latter.

overlapping of the critical points, and a tendency to irregular distribution of the ferrite. The steels will all appear to consist almost entirely of pearlite.

The initiation of crystallization in eutectoid steels only occurs when the lines fF or cC are reached. The temperature at which recalescence begins will, therefore, here reach a minimum, but formation of pearlite will proceed freely when once started. For the same reason a steel somewhat below the eutectoid composition can the more easily be cooled out without the appearance of free ferrite or troostite[28].

(*d*) *Appearance of Marginal Carbide in Pearlite in Hypoeutectoid Steels.* —It will be observed that if the recalescence initiated at C′ carries the austenite to a state represented by a point above the line oC', the growth of ferrite will cease, for the austenite is no longer metastable with respect to ferrite. Cementite, however, will continue to grow on existing nuclei. In the cases discussed above, the speed of cooling is assumed to be sufficient to keep the conditions below oC'; if, however, the austenite has attained the state C′ throughout, either by slow cooling as in a large casting, or by long diffusion in a small area between the points Ar3 and Ar1, as in a low-carbon steel, the recalescence will carry the temperature above oC' and carbide alone will crystallize on the margins of the austenite. Meanwhile the interior will be brought back by diffusion and cooling to a point within the line oC' but nearer o, and will crystallize as pearlite. Cementite margins of this nature are well known, and have been attributed to "divorce" of the pearlite, but this explanation fails to account for the relatively greater frequency of the effect in the low-carbon steels.

The Eutectoid Structures

In the preceding account two distinct types of pearlite formation have been indicated, occurring near the points F′ and C′, for hyper- and hypoeutectoid steels respectively. This corresponds, as above explained, with the well-known fact that the critical point is distinctly higher for the hypereutectoid steels than for those in which free cementite is not present.

The formation of eutectic structures was at first regarded by Miers as occurring in the neighborhood of the hypereutectic point. Sections of preparations formed under such conditions have, however, generally indicated a finely granular structure corresponding with shower-precipitation, and the characteristic interlocking of the constituents was rarely, if ever, obtained. It seems clear in the present case that the eutectoid structure is characteristic of growth in the metastable state, but at points which may lie very close to the equilibrium curves; the conditions for propagation of the structure being that the solution shall be metastable with respect to *both* constituents and that nuclei of both shall be present (*i.e.*, the representative point shall lie within the eutectic area $opo'q$.)

The removal of one constituent by crystallization at once leaves the other in excess. The precipitation of the latter is then accelerated and so the eutectic grain grows with a continuous boundary, even if the natural rates of crystal growth of the constituents differ considerably. If one constituent is present in predominant amount, the eutectic grains usually assume a crystalline form approximating to that of the dominant constituent. It is necessary to emphasize the fact that the eutectic structure has nothing in common with dendritic growth. The latter occurs in the lower part of the metastable range[15] and has a highly distorted crystal habit. The eutectic, on

the other hand, is formed at temperatures but little below equilibrium, and may have a quite normal crystal habit for the dominant constituent. In the eutectic the interfaces between the constituents are often irregular or are the nature of "combination-planes," while in free dendritic growths the outline is determined entirely by the symmetry of the one constituent concerned.

The form of the recalescence curve at Ar1 is extremely characteristic. It consists of a steep rise from the point of inoculation, followed by a period of constant temperature, after which cooling sets in as the crystallization is completed. It is most significant that when the rate of cooling is increased the temperature of the level part of the curve is depressed, although the constancy of temperature is still maintained[28]. The explanation of this is to be found in the fact that the rate of crystal growth increases as the temperature falls below equilibrium. This results in an increased rate of evolution of heat, and so far various rates of cooling corresponding temperatures exist at which the heat evolved in crystallization balances the heat removed by cooling and constancy of temperature results.

As is well known, the more rapid the cooling of a sample the finer the pearlite; fine pearlite must therefore be regarded as characteristic of rapid crystallization. It may be worth while to examine briefly the causes that determine the spacing of the pearlite lamellæ.

Every growing crystal is surrounded by a film in which the concentration varies quickly from approximate saturation at the growing surface to the condition of the surrounding liquid. The steepness of the gradient in this film depends on the coefficient of diffusion of the crystallizing substance. If two crystals approach close together they will compete for the dissolved material, and growth will diminish when they come within a range depending on the thickness of the surface layer. This is well seen when two dendrites meet in a crystallizing drop; growth ceases, and there remains a clear space of liquid between the crystals. There is thus a limit within which two crystals cannot grow rapidly side by side. If growth is slow, diffusion operates to a considerable distance and the interspace is wide, but if growth is rapid the crystals can approach more nearly together and the dendritic structure has a finer grain. Now in pearlite the exposed surface of each cementite lamella grows by diffusion from the surrounding austenite; round each lamella will be a saturated zone, and should two lamellæ approach too closely their growth will be arrested; if, on the other hand, the lamellæ are too far apart, the cementite in the intervening region must be deposited on a fresh nucleus or on branches from neighboring lamellæ. Thus for each condition of formation there will be a characteristic average spacing, which gets closer as the rate of growth increases.

Supersaturation Effects on Rapid Cooling: Martensite and Troostite

Three characteristic temperatures govern shower-precipitation in the labile state; they are: (1) The equilibrium point; (2) the supersaturation point at which the shower appears; (3) a point, or rather a range of temperature, below which crystal growth is completely arrested owing to viscosity or to lack of crystallization-velocity.

Recent researches have made it clear that martensite is a fine aggregate of *a*-ferrite crystals. The temperature at which this aggregate is formed, by a shower-precipitation, is determined as about 350 degrees Cent. for approximately eutectoid steel[28], and is the recalescence point Ar″. It has been

identified by Dejean[24] with the point Ar3, depressed by extremely rapid cooling. This view is opposed by Portevin[25], who regards it as a point of "labile equilibrium," between austenite and a labile solid solution of carbide in α-ferrite. In the following note it will be treated simply as a supersaturation point analogous with those observed in solutions in which spontaneous crystallization occurs without stirring.

Both Guillet and Portevin agree that the point rises with diminishing carbon content, so that the supersaturation curve $o'a'$ will have a course

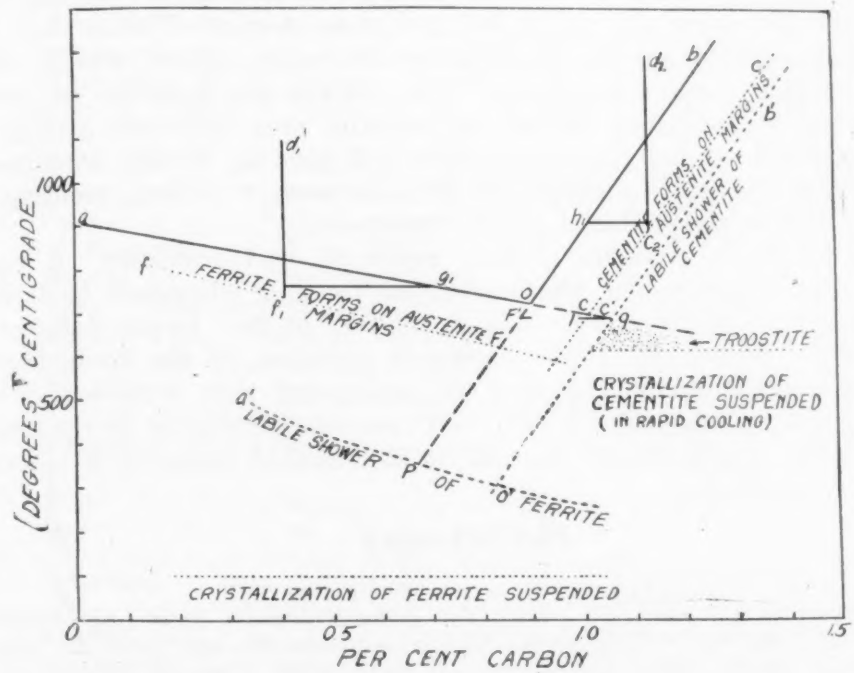

Fig. 1—Diagram to Illustrate Delayed Crystallization in ordinary Carbon Steels

Note.—In order to simplify the diagram, the ferrite curve is represented as a straight line and the temperatures on the cementite curve are greatly exaggerated. The gradients near the eutectoid point are approximately correct.

such as is shown in Fig. 1. The region of suspended crystallization sets in below 100 degrees Cent., beyond which austenite undergoes little, if any, decomposition. When once the shower has appeared the supersaturation curve has no significance; there is thus no corresponding critical change on tempering. The latter consists in the grain-growth of α-ferrite and in the agglomeration of carbide, hence the close resemblance between the course of tempering and that of grain-growth.

Troostite is encountered mainly in the higher carbon steels and in hypoeutectoid steels in which the austenite areas have approached eutectoid composition. On rapid cooling of the latter class the troostite appears only at the margins between the austenite and the ferrite while the interior passes into martensite. These grain-margins represent regions in which the carbon is most concentrated, and troostite therefore seems to be a constituent only obtainable in the neighborhood of the eutectoid composition**. The temperature of formation of troostite, Ar′, varies from 665 degrees Cent. in a high-

** This refers only to the troostite formed in directly cooled steels, and not to the fine temper-structure also sometimes called by this name. In the same way "pearlite" is used with reference only to the eutectoid aggregate and not to any aggregate of cementite and ferrite, however derived.

carbon steel to 635 degrees Cent. on rapid cooling. Beyond this stage the critical rate of quenching is reached and the point is not further depressed but vanishes, its place being taken by Ar″ at 350 degrees Cent. with formation of martensite. The physical properties of troostite show that it is a mixture of α-ferrite and cementite[23].

The formation of troostite may be explained as follows: On the supersaturation theory, shower-precipitation of cementite will occur when a steel passes the line $o'b'$, the supersolubility curve for cementite. This curve, which will be roughly parallel with the equilibrium curve, is very steep, and so the low-carbon austenites can only yield martensite. A further restriction is, however, necessary; since Ar′ cannot be depressed below 635 degrees Cent., it follows that at this temperature the range within which cementite cannot crystallize must supervene. The shower-precipitation of cementite will therefore not originate below the troostite area indicated in Fig. 1. A patch of austenite of variable composition will thus be divided into two areas —the richer, which passes through the troostite area on cooling, yielding troostite, while the less concentrated yields martensite††.

The α-ferrite in troostite is in a relatively soft condition; it does not represent a ground-mass of martensite, but must be supposed to have originated at the high temperature. The formation of this ferrite follows necessarily through inoculation by the cementite particles of the labile shower at some point a little below. It may be anticipated that with higher carbon steels the point Ar′ may be divided into two, one belonging to the cementite shower and one of the transformation of the residual austenite by inoculation at a lower temperature.

REFERENCES

(a) On the Supersolubility Curve, Etc.

1. MIERS (H. A.) and ISAAC (MISS F.): "The Refractive Indices of Crystallizing Solutions with Especial Reference to the Passage from the Metastable to the Labile Conditions." *Journal of the Chemical Society,* vol. 89, pp. 413-454, 1906.
2. HARTLEY (H.) and THOMAS (N. G.): "The Solubility of Triphenylmethane in Organic Liquids with which it forms Crystalline Compounds." *Journal of the Chemical Society,* vol. 89, pp. 1013-1033, 1906.
3. MIERS (H. A.) and ISAAC (Miss F.): "The Spontaneous Crystallization of Binary Mixtures. Experiments on Salol and Betol." *Proceedings of the Royal Society,* Lond., A., vol. 79, pp. 322-351, 1907.
4. JONES (R. M.): "The Spontaneous Crystallization of Solutions of some Alkali Nitrates." *Journal of the Chemical Society,* vol. 93, pp. 1739-1747, 1908.
5. MIERS (H. A.) and ISAAC (Miss F.): "The Spontaneous Crystallization of Substances which form a Continuous Series of Mixed Crystals. Mixtures of Naphthalene and β-Naphthol." *Journal of the Chemical Society,* vol. 93, pp. 927-936, 1908.
6. ISAAC (Miss F.): "The Temperatures of Spontaneous Crystallization of Mixed Solutions, and their Determination by Means of the Index of Refraction. Mixtures of Solutions of Sodium Nitrate and Lead Nitrate." *Journal of the Chemical Society,* vol. 93, pp. 384-411, 1908.
7. HARTLEY (H.), JONES (B. M.), and HUTCHINSON (G. A.): "The Spontaneous Crystallization of Sodium Sulphate Solutions." *Journal of the Chemical Society,* vol. 93, p. 825, 1908.
8. HARTLEY (H.) and BARRETT (W. H.): "Sodium Sulphite and its Equilibrium with Water." *Journal of the Chemical Society,* vol. 95, pp. 1178-1185, 1909.

†† These remarks relate to the rapid cooling necessary to bring the sample past the condition at which pearlite forms. If, by interrupting the quenching, the steel is held for some time below the troostite area but above the martensite point, troostite will appear, as shown by Portevin and Garvin (28).

9. Isaac (Miss F.): "On the Spontaneous Crystallization and the Melting and Freezing-Point Curves of Mixtures of Two Substances which form Mixed Crystals and Possess a Minimum or Eutectoid Freezing-Point. Mixtures of Azobenzene and Benzylaniline." *Proceedings of the Royal Society*, Lond., A., vol. 84, pp. 344-369, 1910.

10. Miers (H. A.): "An Enquiry into the Variation of Angles observed in Crystals." *Philosophical Transactions of the Royal Society*, Lond., A., vol. 202, p. 515, 1903.

11. Ostwald (W.): "Studien uber die Bildung und Umwandlung fester Korper." *Zeitschrift Physicalische Chemie*, vol. 22, pp. 289-330, 1897.

12. Tammann (G.): "Ein Verfahren zur Erzwingung Spontaner Kristallization." *Zeitschrift Anorganische Chemie*, vol. 87, pp. 248-252, 1914.

(b) On Inoculation and Parallel Growth of Crystals

13. Barker (T. V.): "Contribution to the Theory of Isomorphism based on Experiments on the Regular Growth of Crystals of One Substance on those of Another." *Journal of the Chemical Society*, vol. 89, pp. 1120-1158.

14. Miers (H. A. and Chevalier (J.): "On the Crystallization of Sodium Nitrate." *Mineralogical Magazine*, vol. 14, pp. 123-133, 1906.

15. Chevalier (J.): "On the Crystallization of Potash Alum." *Mineralogical Magazine*, vol. 14, pp. 134-142, 1906.

16. Barker (T. V.): "On the Regular Growth of Soluble Salts on each Other." *Mineralogical Magazine*, vol. 14, pp. 235-257, 1907.

17. Miers (H. A.): "Note on the Crystallization of Potassium Bichromate." *Mineralogical Magazine*, vol. 15, pp. 39-41, 1908.

18. Barker (T. V.): "The Question of a Relation between Parallel Growths of Crystals and Isomorphous Miscibility, and the Bearing of Parallel Growths on Questions of Isomorphism." *Mineralogical Magazine*, vol. 15, pp. 42-53, 1908.

19. Beilby (G. T.): "Surface Flow in Calcite." *Proceedings of the Royal Society*, Lond., A., vol. 82, pp. 599-605, 1909.

20. Chevalier (G.): "Note on the Spontaneous Crystallization of Drops as Spherulites." *Mineralogical Magazine*, vol. 15, pp. 224-231, 1909.

21. Kreutz (S.): "Contribution to the Study of Parallel Growths of Different Substances." *Mineralogical Magazine*, vol. 15, pp. 232-237, 1909.

22. Barker (T. V.): "Crystallographic Notes on Inosite, Potassium Nitrate, and Urea Nitrate." *Mineralogical Magazine*, vol. 16, pp. 207-216, 1912.

(c) On Steel, Etc.

23. Chevenard (P.): "Mechanisme de la trempe des aciers au carbone." *Revue de Metallurgie*, vol. 16, pp. 17-79, 1919.

24. DeJean (P.): "Sur la Nature des transformations qui se produisent pendant la trempe des aciers." *Revue de Metallurgie*, vol. 18, pp. 419-427, 1921.

25. Portevin (A) and Chevenard (P.): "Remarques et observations concernant les phenonomenes de trempe des aciers." *Revue de Metallurgie*, vol. 18, pp. 425-444, 1921.

26. Portevin (A.) and Chevenard (P.): "La dissolution retardee et la precipitation prematuree du carbure de fer. . ." *Comptes Rendus*, vol. 173, pp. 1490-1493, 1921.

27. Portevin (A.): "Principes et phenomenes generaux relatifs a la cristallization, a la solidification et a la devitrification." *Revue de l'Ingenieur*, vol. 28, p. 165, 1921.

28. Portevin (A.) and Garvin (M.): "The Experimental Investigation of the Influence of the Rate of Cooling on the Hardening of Carbon Steels." *Journal of the Iron and Steel Institute*, 1919, No. I, pp. 469-559.

29. Ritzel (A.): "Kristallizations- und Auflosungsgeschwindigkeit." *Fortschritte der Mineralogie*, vol. I, pp. 86-98, 1911.

30. Williamson (E. D.): and Adams (L. H.): "Temperature Distribution in Solids during Heating or Cooling." *Physical Review*, N.S., vol. 14, pp. 99-114, 1919.

31. Bowen (N. L.): "Diffusion in Silicate Melts." *Journal of Geology*, vol. 29, pp. 295-317, 1921.

32. Tutton (A. E. H.): "Crystalline Structure and Chemical Constitution." London, 1910.

SOME FATIGUE TESTS OF SPRING STEELS

By R. E. Lewton

Abstract

Fatigue tests and investigations have been the basis of many researches in the past few years. The engineer as well as the metallurgist has been very much concerned with the apparently uncertain factor of the fatigue resisting properties of a given steel. The author of this paper presents some very interesting data obtained in the testing of leaf springs for automotive purposes and outlines the procedure and the results obtained in testing five different types of steels. No mathematical expressions of the relationships between the various factors affecting the ultimate properties of the steels has been formulated.

Introduction

IN THIS paper, the writer has outlined the procedure and subsequent results of a series of tests which were made in the hope of determining a suitable means of comparing different types of spring steels. Whether successful or not, certain observations were made which may be of interest and value.

Fundamental Principles Reviewed

At the outset, it seems desirable to review some of the fundamental principles governing the behavior of metals under loading. When a piece of steel is subjected to a load tending to pull it apart, the piece stretches an amount which is proportional to the load applied. For short lengths, this stretch is imperceptible except with the aid of delicate micrometers. Unless the load applied exceeds a certain value, the piece will regain its original length when the load is removed. If, however, the load used does exceed this limiting value the piece will retain a certain increase in length which is known as "set." Furthermore, above this limit the stretch increases at a much faster rate than before the limit was reached. In other words, there is a point in the loading beyond which the increase of load and increase of stretch are no longer proportional in a definite ratio. This value is commonly called the "proportional limit."

The value for the proportional limit varies with different materials and different treatments but it can readily be determined by suitable laboratory tests. In general, it may be said to occur in steel when the load is ½ to 9/10 of that required to cause failure in the ordinary tension test. All machine and structural parts are designed to work at loads considerably below this limit as experience has shown that even at values much below, there is liability to failure in service. The cause of such failures was formerly considered due to a very indefinite phenomenon called "crystallization," but this explanation has long since been discredited by the experiments of some of our foremost investigators.

These men went about to determine how metal, and especially steel, be-

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haves under repeated stresses, and some surprising results have been obtained. Much has been learned by the use of so-called fatigue or repeated stress machines, particularly those types known as the alternating bend machines. A machine of this type (Fig. 2) was used in the tests about to be described.

Before going into detail as to the operation of the machine, it might be well to consider briefly what happens when a piece of steel is bent. Fig. 1 shows a sketch illustrating a rectangular beam supported at each

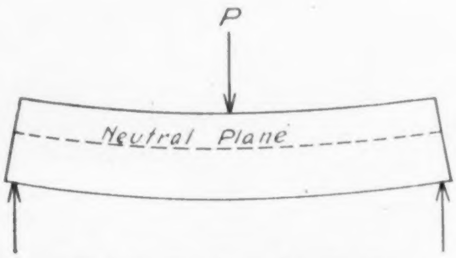


Fig. 1—Sketch Showing the Bending of a Beam When Supported at Either End and Loaded in the Center.

end and loaded in the middle. When the load is applied the upper surface becomes shorter and the lower surface becomes longer while a plane midway between neither shortens or lengthens. Since the lower surface has lengthened the load has acted on that portion of the bar in such a way as to set up tension forces within it. Likewise the upper surface must be in compression. The neutral plane, since it is neither lengthened nor shortened, is neither in tension nor compression. The beam supports the load in the middle by virtue of certain reactions within the bar which are known as stresses. The tension which is in the lower part of the bar and the compression which is in the upper part of the bar is there as a direct result of the application of the load in the middle. Tension and compression then are both forms of stress and are due to the resistance which the bar offers to the load applied. When the load is too great the tension and compression forces or stresses become too great and the bar fails. The point which the author desires to make is, that bending introduces stresses in materials just as does an ordinary tension or compression load. There is this difference, however, that in bending, the tension stresses are not evenly distributed throughout the lower half of the bar but are greatest in those surfaces farthest from the neutral plane and become less and less until at the neutral plane the stress is zero. Also the compressive forces are greatest at the concave surface farthest from the neutral plane and taper off to zero at the neutral plane. This irregular distribution of stress within the bar helps to account for some of the peculiarities of fracture observed in pieces which have failed in fatigue. Since the outermost fibers are under greater stress than those nearer the neutral plane, it is but natural that those fibers should fail first when under load and this is just as true of pieces in repeated stress loading as it is of pieces broken by a single application of load.

When a part fails in fatigue it does not just suddenly break off but failure is a gradual growth beginning at one or more points of weakness. Then as these weaker points give way the load formerly carried by them is thrown upon neighboring particles which may be nearly as weak as those which have already failed.

At one time, the writer desired a special spring made up in a hurry and as the quenching machines were not set up for that particular spring, the foreman volunteered to have the spring made up by hand. The man who regularly did such work was off that day and another was delegated to do the job. When the built-up spring failed at half the life expected of it, and examination was made of the broken plate with the result shown in

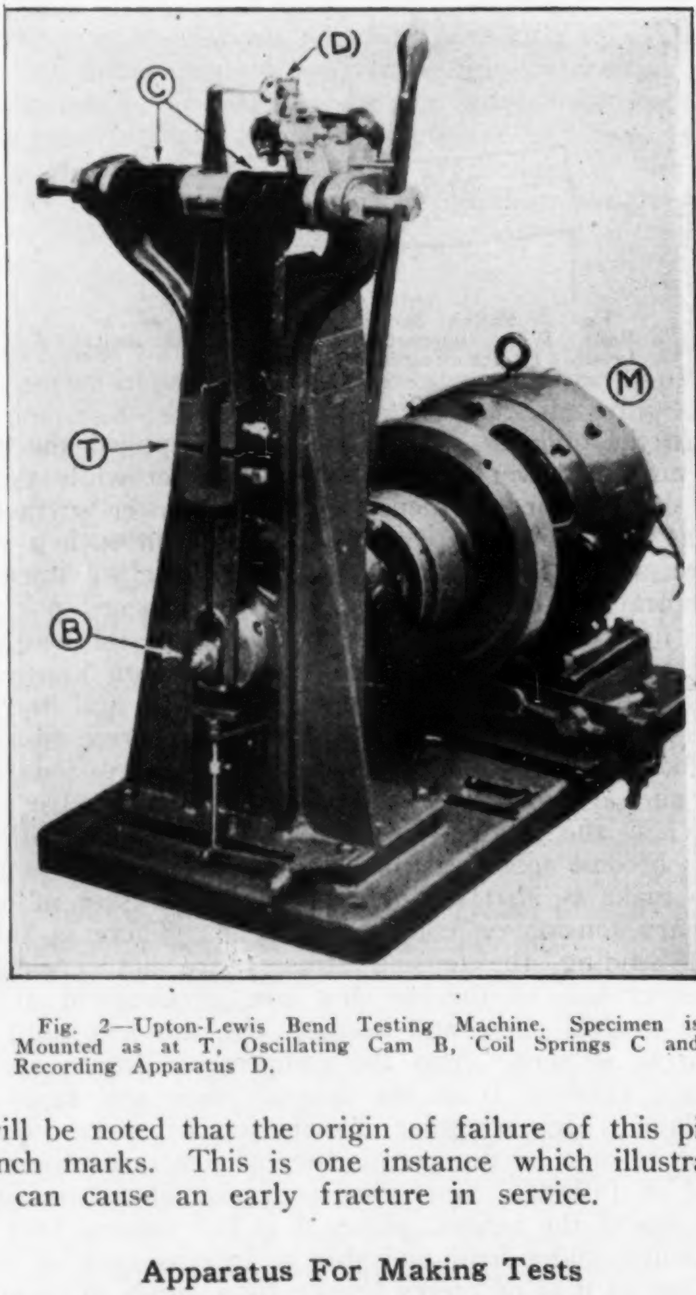


Fig. 2—Upton-Lewis Bend Testing Machine. Specimen is Mounted as at T, Oscillating Cam B, Coil Springs C and Recording Apparatus D.

Fig. 3. It will be noted that the origin of failure of this piece was at the two prick-punch marks. This is one instance which illustrates how small imperfections can cause an early fracture in service.

Apparatus For Making Tests

The Upton-Lewis alternating bend testing machine was used in making the tests described in this paper. It is shown in Fig. 2. The test is made by mounting the test specimen in the clamp jaws as shown at *T* in Fig. 2. The motor-driven cam at *B* oscillates the lower specimen jaw which transmits the strain through the test piece (bending it slightly) to the upper

jaw mounted between two coil springs *C*. The extension to the upper jaw transmits its vibrations to a recording device *D* which keeps a record of the number and amplitude of the vibrations.

From this it is seen that when the test piece is bent first in one direction and then in the other, the outermost fibers are first in tension, then in compression and then back in tension and so on until the piece breaks. The change from tension to compression and back to tension again is called

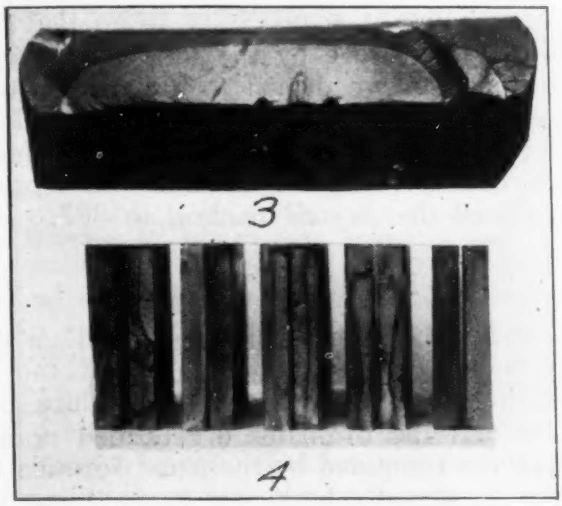


Fig. 3—Fracture of Special Spring. Note that Failure Started at the Two Prick-Punch Marks. Fig. 4—Types of Fractures Usually Obtained on Specimens Tested in the Upton-Lewis Machine.

a cycle and the life of a test is spoken of in terms of cycles. Fig. 4 shows the type of fracture resulting in tests made with the Upton-Lewis machine.

Steels Tested

The tests which are referred to in the introduction of this paper were made on five different types of steel, plain carbon, chrome-manganese, chrome-molybdenum, U. M. A. and chrome-vanadium, the analysis of each

Table I

Chemical Analyses of Steels Tested

Type of Steel	Carbon Per Cent	Manganese Per Cent	Phos. Per Cent	Sul. Per Cent	Si. Per Cent	Cr. Per Cent	V. Per Cent	Mo. Per Cent
Carbon	.91	.45	.020	.035	.11	...	...	...
Chrome-Manganese	.46	.95	.020	.025	.05	.88	...	...
Chrome-Molybdenum	.48	.95	.020	.035	.24	1.22	...	.18
U. M. A.	.46	.85	.020	.018	.14	1.04	.16	...
Chrome-Vanadium	.49	1.00	.020	.022	.26	1.18	.16	...

type being shown in Table I. Bars of No. 1 gauge steel 2 inches wide were obtained and ten or more 5-inch lengths were cut from each. These pieces were then heat-treated and sent to the grinding room with instructions to grind to finish on both faces and edges. No extraordinary care was used

on these pieces except to be sure that the grinding marks did not run crosswise. After grinding, each piece was gripped in the vice and the corners slightly rounded by the use of fine emery cloth, the object being to minimize the possibility of premature fractures originating at the corners.

Heat Treatment

For heat treatment a quenching temperature of 1600 degrees Fahr. was used in all cases. Inasmuch as it is the practice in our shops to quench with the aid of the forming machine it is necessary to go that high if the steel is to be above the critical temperature by the time it reaches the oil. Except for the carbon steel all bars were drawn to a hardness of 418-430 Brinell, using the temperature previously determined experimentally on other pieces. As the carbon steel pieces were only 402 Brinell after quenching they were given the draw which was at that time used in the shops, namely 825 degrees Fahr.; which reduced the Brinell reading to 387.

Results of Tests

Figs. 5 to 9 show in detail, the results obtained on each type of steel tested. Each curve represents the behavior of one of the 5-inch test pieces from the time of the first loading to complete failure. The abscissa of these curves are cycles and the ordinates are termed nominal stress. This means the stress in the piece computed by the usual formula which assumes the piece to be solid until it is actually broken in two. Since in its very nature fatigue failure is a progressive break taking place over a considerable period of time this is not a correct assumption, but by plotting the values so obtained some interesting things are revealed.

Once a test piece begins to fail the experimenter loses control of the stresses in the piece for he has no means of knowing where the failure is nor how large it is, and without this information, has no means of allowing for the change by the proper computations. Fig. 5 shows the curves obtained in the tests on the plain carbon steels. The fact that the piece is weakened is evident on the curves, for the ability of the piece to stand up under the action of the machine becomes less and less until complete failure has taken place.

Figs. 5, 6, 7, 8 and 9 show the history of a series of pieces run to failure at different stresses. In general the higher the stress the quicker the failure, as is to be expected, but as will be noticed by observing how nearly the individual curves approach the dotted line above, it will be seen there seems to be a serious lack of uniformity in the results, especially in the case of the carbon steels.

In interpreting the results of fatigue tests, it has been the custom to plot values for stress against the number of cycles to cause failure. The results of such a plotting of the data just presented are summarized in Fig. 10.

In a sense, Fig. 10 illustrates that steels of the same hardness seem to have similar fatigue characteristics. However, a point which is not shown, is that each curve is only an average and that several points fall wide of the curve as drawn. It is this failure to get uniform results in test pieces which are stressed to a point sufficient to cause failure in a few hundred thousand cycles, which has caused many investigators to abandon and hold as valueless such short-time high-stress curves, and they turn to tests to de-

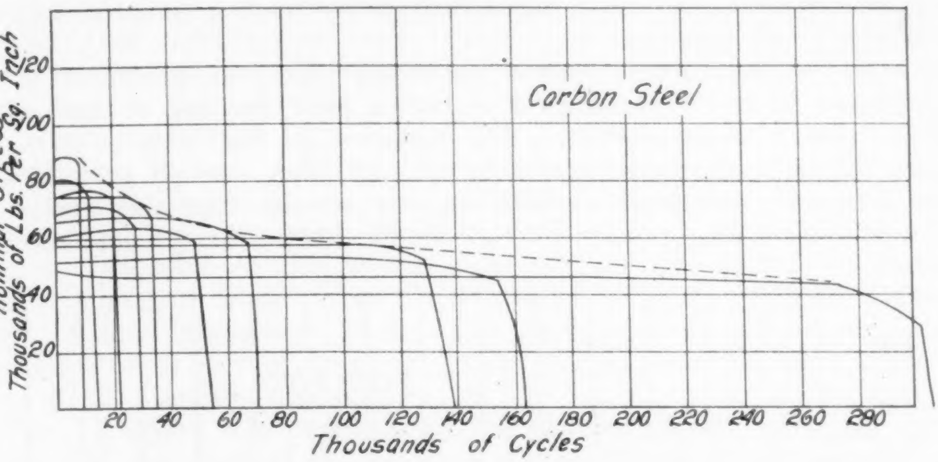


Fig. 5—Curves Obtained in the Tests of Carbon Steel. Steel Quenched from 1600 Degrees Fahr. and Drawn at 825 Degrees Fahr. Analysis of Steel Shown in Table 1.

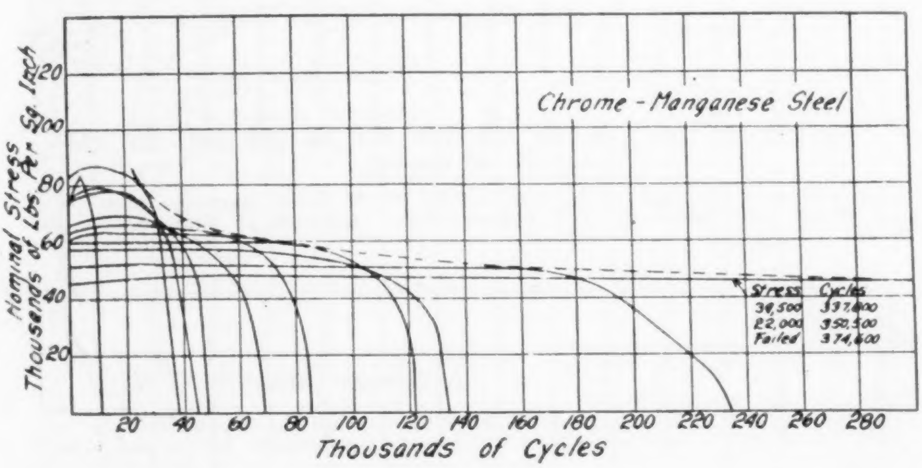


Fig. 6—Curves Obtained in the Tests of Chrome-Manganese Steel, Quenched from 1600 Degrees Fahr. and Drawn at 900 Degrees Fahr. Analysis of Steel Shown in Table I.

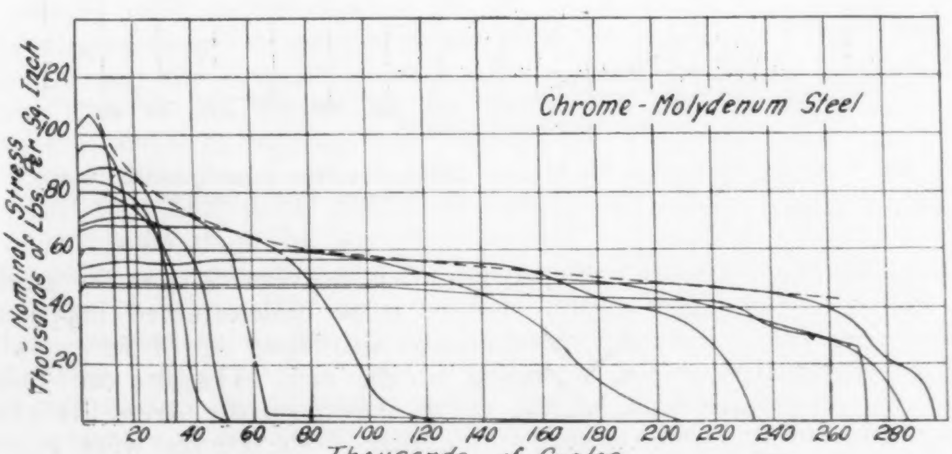


Fig. 7—Curves Obtained in the Tests of Chrome-Molybdenum Steel, Cooled in Furnace After 1 Hour at 1650 Degrees Fahr., Quenched in Oil From 1600 Degrees Fahr. and Drawn at 950 Degrees Fahr. Analysis of Steel Shown in Table I.

termine the fatigue limit or the maximum stress which a material will stand indefinitely without failure.

A study of the curves for the individual pieces as presented in Figs. 5, 6, 7, 8 and 9 shows one important reason why the use of the ordinary stress-life curve is unsatisfactory. For instance, in Fig. 9 it is shown that after two of the pieces were nearly broken off, they seemed to take a new lease on life and continued to hold on for several thousand cycles after failure would have been expected. This is due to the fact already mentioned

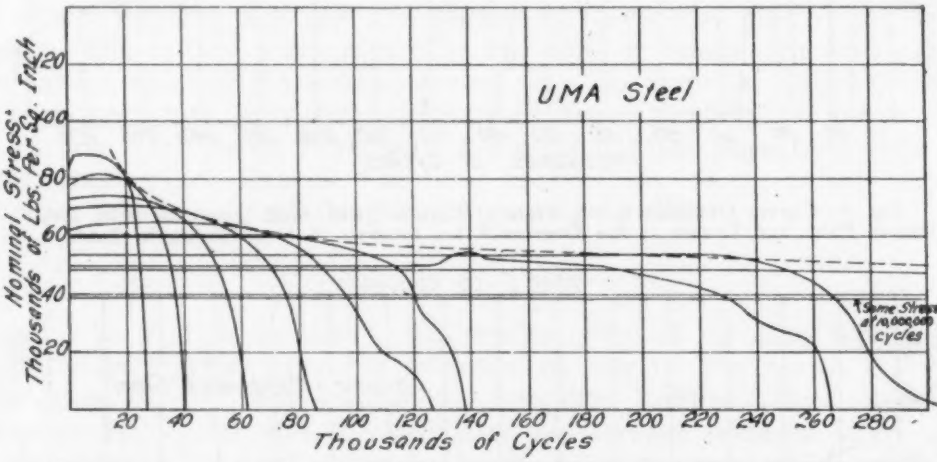


Fig. 8—Curves Obtained in the Tests of U. M. A. Steel, Quenched from 1600 Degrees Fahr. and Drawn at 825 Degrees Fahr. Analysis of Steel Shown in Table I.

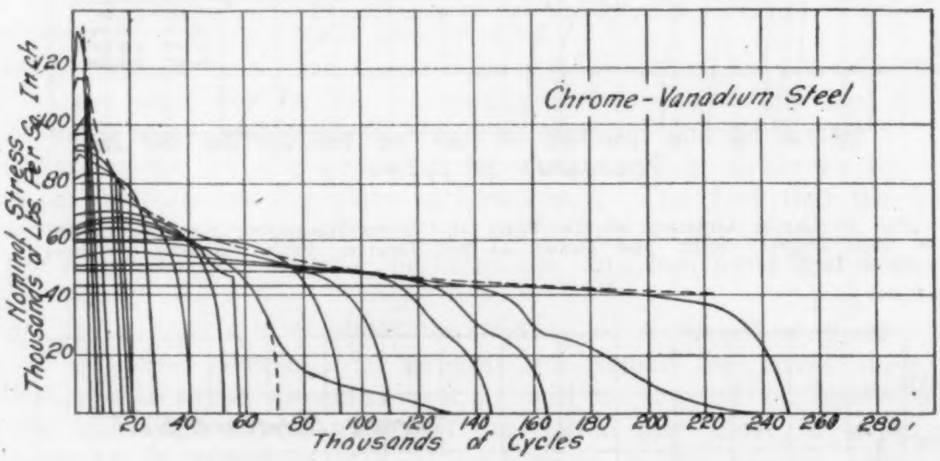


Fig. 9—Curves Obtained in the Tests of Chrome-Vanadium Steel, Quenched from 1600 Degrees Fahr. in Oil and Drawn at 900 Degrees Fahr. Analysis of Steel Shown in Table I.

that once a piece begins to fail, the operator has no control over the stresses actually exerted on the test piece. Due to some undetermined happenings within the piece the stresses are more evenly distributed or of lesser values than were contemplated at the beginning of the run. The life at failure for these two pieces was wide of the curve shown on the stress-life chart. It is interesting in this connection to note that if the curves were to continue in a manner similar to the other curves of the series, the life would correspond very closely to the average stress-life curve.

In view of the fact, however, that after failure begins the observer

has lost control of the behavior of the test piece, and also in view of the fact that after failure has once begun to take place, the material is of no value as a part of a structure, it seems that it would be more instructive to study curves showing the relationship of stress to the life at the point where failure is only beginning. Just where this point is, is hard to determine; in fact, failure under the stresses used in the present tests may be said to begin at the first application of stress. However, in plotting the data here presented, it was noticed that a tangent drawn to the upper part of some of the curves, especially for the chrome-vanadium steel, was also a tangent or nearly so to the curves for the same steel subsequently plotted. Closer inspection shows that tangents so determined touch the individual history curves at points at or just beyond the time when failure begins to be rapidly accelerated.

Fig. 11 shows a comparison of the different steels using the tangential curves. On the face of it, we seem to have arrived at a conclusion op-

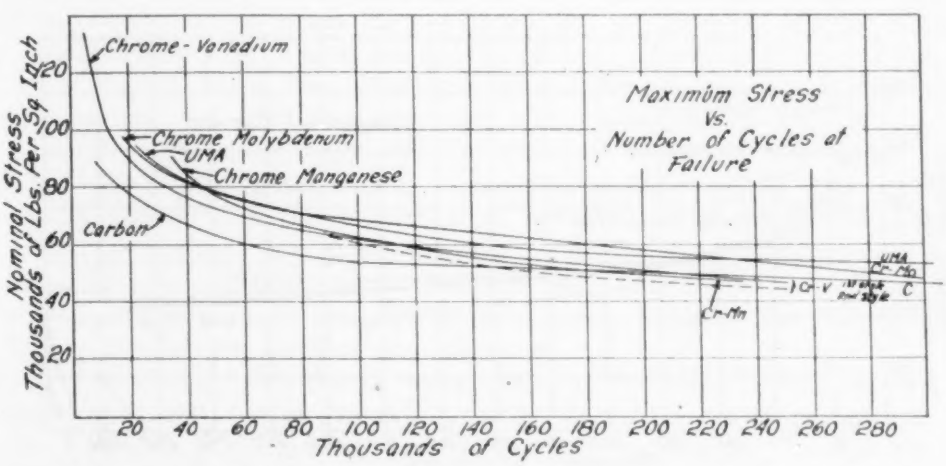


Fig. 10—Results of the Fatigue Tests of Steels Shown in Figs. 5 to 9 Plotting the Values of the Stresses Against the Number of Cycles to Cause Failure.

posite to that which was hoped for. Instead of finding a marked difference in the steels, we find their fatigue characteristics much more nearly the same than was anticipated in the stress-life curves. On the other hand the results tend to substantiate the findings at the University of Illinois (The Engineering Foundation, report for the year ended February 9, 1922, page 64) that the Brinell hardness may be taken as a fair index of the endurance limit. The writer has not determined any endurance limits but it seems reasonable to suppose that the behavior of a material at stresses above the fatigue limit has a definite relation to the behavior at the fatigue limit.

The fact that these tangential curves, then, are shown to give more uniform results than the stress-life curves, and that this uniformity is entirely in accord with the findings of the most recent investigations has led the writer to believe that the tangential curves are a more satisfactory basis for the comparison of the fatigue properties of steels than the usual stress-life curves. Also these curves are more quickly determined as it is not necessary to run the test to complete failure of the pieces.

In what way can such curves be of value?

If any of you were asked what one of the steels discussed in this paper was likely to give the shortest life and which would give the longest under similar service conditions, you probably would all answer "carbon steel"

to the first question and "chrome-vanadium steel" to the second. Now, then, referring to the charts again, as judged by the ability of each and every piece in the series for each kind of steel, to register on the dotted line the carbon steel was the one to give the most irregular results and the chrome-vanadium and U. M. A. steels were the most regular. Chrome-manganese springs have a rather poor reputation and that steel gave irregular results in our tests. The writer has no service records to compare with the findings of this test as regards chrome-molybdenum steel.

This correlation of variations with the known service records for the steels is in accord with the theories as to the nature of fatigue failures as discussed in the Engineering Foundation Report (page 57) from which the following is quoted:

"This theory may be called the theory of non-homogeneity or of localized stress. The effect of external non-homogeneity due to scratches, tool marks, square shoulders, and notches is well known. Internal non-homogeneity

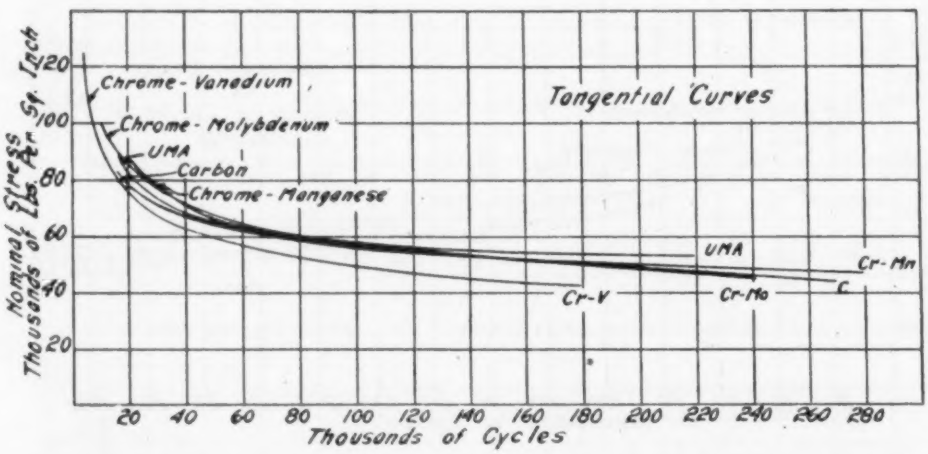


Fig 11—Comparison of Steels as Shown in Figs. 5 to 9 Using the Tangential Method of Plotting.

may be due to blow holes, pipes, inclusion of slag, irregularity of crystalline structure on account of the presence of two or more constituents of varying strength, variation in orientation of crystals or the presence of initial stresses caused by mechanical working or heat treatment. Owing to the minute area over which it exists, this localized stress produces no appreciable effect under a single load, but under load repeated many times, there is started from this area a microscopic crack, at the root of which there exists high localized stress which under repetition of stress spreads until it finally causes failure.

"The writers do not look upon these fatigue failures as being due necessarily to accidental flaws or irregularities. Such failures may, in practice, often be due to such causes, but the definiteness of the endurance limits found in the present tests points to the conclusion that the endurance limit is a property of the material just as much as the ultimate strength. If in these tests the failure is due to flaws, then it is believed that these flaws are an inherent part of the structure of the particular steel which is being tested."

Does it not seem reasonable that the variations seen in the individual curves for the carbon steel and almost lacking in the chrome-vanadium steel are due to these non-homogeneities? And, further, does it not seem reasonable that the more pronounced the lack of homogeneity the greater will

be the variations among the individual history curves for the various pieces? The writer believes that such will be found to be the case.

This reasoning suggests that if some means were evolved to express the variations observed in relation to some value or values accepted as standard we might have a convenient means for the expression of the relative fatigue properties of steels. In the light of the previous discussion, it is believed the tangential stress-life curve offers a suitable standard for this purpose, and that the variations from this standard shown by individual pieces of steel of a given analysis and treatment can be used as measures for the comparison of a steel with other steels and heat treatment with heat treatment.

Conclusion

The writer has not tried to express this relation mathematically, although probably that is ultimately desirable, the limited figures available being hardly sufficient to warrant the attempt. A procedure which might be instructive would be to draw curves more or less parallel to the tangential curves which would be tangential to the curves showing the shortest lives. The area between these two tangents would be of help in comparing the variations in one set of test pieces with the variations in another set.

As to the data assembled and the conclusion drawn, the author is not unmindful that more information is necessary before they are given unqualified acceptance, but the existence of greater variations in the individual curves for the carbon steel than are found in the corresponding curves for the better chrome-vanadium steel is so obvious and so in harmony with the present day theories as to the nature of fatigue failures, that the matter at least seems worthy of further investigation.

Since the charts here shown were prepared we have tested another series of carbon steel test pieces, resulting in a tangential curve somewhat higher than the first one but showing just as marked variations. This latter series was the same as the first in every way except that the draw used was 900 degrees Fahr. instead of 825 degrees Fahr., which would indicate the 900 degrees Fahr. draw to be the better. We are at present running another series of the chrome-vanadium test pieces made from another bar of stock and the tangential curve apparently will fall very close to the one shown. The variations are slightly more noticeable than in the previous test.

DISCUSSIONS OF PAPERS PRESENTED BEFORE THE TECHNICAL SESSION OF THE DETROIT CONVENTION OF THE SOCIETY, THURSDAY MORNING, OCTOBER 5, 1922

THE Thursday morning technical session of the Society's convention held in Detroit Oct. 2-7, 1922, was called to order at 10:15 a. m. by Chairman Dr. C. M. Johnson, director of research, Crucible Steel Co. of American, Park Works, Pittsburgh, Pa.

Chairman Johnson: I will have to apologize for being late in starting. Perhaps it is just as well, because taking into consideration the late hour of the closing of our entertainment last night, we would not have had very much of an audience if we had started on time.

According to our program, the first paper is by H. J. French, physicist of the Bureau of Standards, and Jerome Strauss, metallurgist of the United States Navy Yard, Washington, on "Lathe Breakdown Tests of Some Modern High Speed Tool Steels."

Mr. French: Mr. Chairman and gentlemen, in view of the fact that this paper has been printed in the TRANSACTIONS, I am going to show you the slides that we have representing most of the tables and figures and pass over them rather hurriedly without going into any considerable detail regarding the basis of our conclusions, inasmuch as the complete data has already been presented. This report is in reality a consideration of so-called 'lathe breakdown tests' for the purchase of high-speed tool steel, a method which has been used considerably in recent years at a number of plants. We make no attempt and have no design to compare so-called 'Taylor tests' with the breakdown tests, in which the endurance of tools is measured under fixed working conditions of speed, feed, depth of cut, etc. In making these tests and going over the data obtained, we found certain general characteristics applied to certain types of steel and the classification was based on chemical composition. For that reason, we have first gone into some detail in the chemical anaylsis of high-speed tool steel as manufactured in this country today. (Mr. French then read excerpts from his paper as published in September, 1922, TRANSACTIONS, and concluded with the following remarks:)

I think that will give you a general idea of some of the data which is included in this report. I want to call attention, however, to the statements which we have made in the summary.

Chairman Johnson: You have heard Mr. French's very interesting paper and the exhaustive nature of it is apparent to everybody. I am sure this is a live topic to practically everybody here. I see some in the audience who undoubtedly would call it a vital topic. I hope we can make the discussion snappy, because we have already been late in starting, and it is now five minutes after eleven, so we will have to proceed very rapidly in order to get through with the other papers.

Mr. d'Arcambal: It is indeed gratifying to note that the results obtained by Messrs. French and Strauss check those obtained by us a couple of years ago, when running breakdown tests on side milling cutters. We also found the low tungsten, high vanadium type of high-speed steel to show the highest cutting effect, followed by the 3½ per cent cobalt, 18 per cent tungsten type of high-speed steel. The

tungstenless high-speed steel was also found to show extremely poor cutting qualities in our milling cutter tests.

We were also glad to note that your results showed that the lower tungsten, higher vanadium type of steel did not stand as high a quenching temperature as would the 18 per cent tungsten type of high-speed steels. For lathe tools, however, a slight coarsening of the grain, as would be obtained on quenching this lower tungsten type of high-speed steel from 2350 degrees Fahr. greatly improves the cutting qualities of the tool, for strength and resistance to shock is not required in a lathe tool or tool bit.

We were pleased to note that you consider the analysis of high-speed steel an important factor as regards one of the means of controlling the uniformity of incoming material. Experience has shown us that it is impossible to buy high-speed steel by brands, because of the great range in analysis received in different shipments. While it is true that the analysis of high-speed steel is no indication of its cutting qualities, nevertheless the purchasing of a certain brand of high-speed steel under strict chemical specifications insures us of manufacturing tools of a uniformly good quality.

Tests have convinced us that high-speed tools not running at high speeds, feeds, etc., perform the most efficiently when quenched from the highest possible temperature. The higher the quenching temperature, the greater the solubility of the carbides and tungstides, and the greater the solution of these carbides and tungstides, the better the cutting efficiency we believe.

There are a few questions I would like to ask the authors. First, is the cutting efficiency of tools improved by quenching from the high draw instead of air cooling?

Mr. French: We have made no tests.

Mr. d'Arcambal: Do you believe the temperature of preheating effects the cutting efficiency of the tool?

Mr. French: So far as I know, it doesn't. I have in my files a statement from a manufacturer definitely showing that the preheating temperature, that is, within certain ranges, I believe between 1400 and 1600 degrees Fahr. has no effect on the performance. But we have no conclusive tests regarding that at the present time.

Mr. d'Arcambal: What success have you had with electric furnaces for the heating of high-speed tools? That is, for the high temperatures?

Mr. French: Some of these tools, quite a few of them, in fact, were heated in electric furnaces of the carbon plate type.

Mr. d'Arcambal: Do you consider the electric furnace as successful as the oil or gas-fired furnaces?

Mr. French: Yes.

Mr. d'Arcambal: Are your tools always run dry in service? I notice that no lubricant was used in the tests.

Mr. French: No.

Mr. Spalding: I would like to compliment the authors on this very interesting paper, and I am particularly interested to see that they have found some of the limits of breakdown testing. Now that corresponds a great deal with some of the work we have done. This is of particular interest to me as I have had occasion to run and be connected with the running of a large number of tests of cutting tools

of high-speed steel. I note that the author's method of comparison is to set some definite condition of speed, feed and depth of cut and determine the time of endurance of the tool under these conditions. Examination of the data obtained in this manner indicates, as the authors point out, that results from different tools from the same bar, and different grinds from the same tools, differ quite widely. It is only by averaging results of at least two grinds on several tools of the same steel that a basis of comparison can be obtained. The presence of such wide differences in test performances would indicate that there was some condition in the test that caused this ultra-sensitiveness.

If these conditions could be changed so that individual runs of the same tools would show fairly close checks, it would seem that better comparative conditions would obtain.

The fixing of speed, feed, and depth, and determining the variable time offers the inducement of simplicity of method, but the erratic results obtained do not, I believe, justify its adoption. In our preliminary work we tried the same methods with similar results. Under identical conditions the same tool might run three minutes one time and six the next. Did this mean that one time it was twice as good as another? No. It meant the test conditions were causing an ultra-sensitiveness, giving exaggerated results.

After much perusal of Taylor's "Art of Cutting Metals," in which he found the same thing, we finally adopted his method of fixing depth of cut and feed and determining the speed required to cause the tool to fail in exactly twenty minutes. By this test method we were able to consistently check our results on the same tool or tools from the same bar. We were able to take a bar of steel, make a tool from it, run it, and determine its twenty-minute speed. Then six months from then if we ran this tool again, or another tool from the same bar, we would find that this same speed would cause it to fail in exactly twenty minutes. These results we found we could duplicate on large numbers of different types of tools within five per cent consistently. Although the Taylor method of determining the twenty-minute speed is a little more difficult in operation, still, due to the fact that since consistent results can be obtained, fewer tools need to be run, usually two tools and two grinds are sufficient. The net result is a saving in time and material which is quite considerable if many steels are to be tested.

As far as testing small tools is concerned, we have been able to do that by the Taylor method, but instead of using the same depth, speed and feed as on larger tools, we used the same feed, but a depth of cut that will give us a twenty-minute speed in the neighborhood of the larger tool, as we think this gives a little better basis of comparison.

Referring to the authors' Table XII of the third series of tests, the variations in individual runs in some cases are extreme. One endurance being anywhere from two to five times the other. It occurred to me that perhaps some of this variation might be due to the annealing and rehardening operations; 1550 degrees Fahr. the annealing heat used, is rather low, in my mind, to thoroughly remove all traces of previous hardening. I would not favor annealing and rehardening of tools for

test purposes, as I believe this only serves to introduce further variables. I think we should stick to tools which have been through the fires only once.

Mr. Strauss: In reply to Mr. Spalding's question, we are not holding any brief for the breakdown test. At the same time we would be very glad indeed to have Mr. Spalding submit some of his data as a part of this discussion, so that we might have an opportunity of analyzing it more closely. It is interesting to note that as the severity of the breakdown test decreases, the results become very much more uniform, and when these values and Mr. Spalding's results are reduced to as near a comparable basis as possible, it may tend to show us the causes of the variations which we have observed.

Dr. Hoffman: I would like to ask Mr. d'Arcambal if he has any parallel to the quenching in oil or cooling in air?

Mr. d'Arcambal: You mean quenching from the draw?

Dr. Hoffman: No.

Mr. d'Arcambal: The question I asked Mr. French referred to quenching from the draw, not from the high temperature.

Dr. Hoffman: I have reference to quenching from the high temperature either air cooling or oil, in either lathe or cutting tools.

Mr. d'Arcambal: The large majority of high-speed tools are quenched in oil so as to eliminate as much as posible the excess scaling that would be produced by air cooling; with the possible exception of high-speed saws, which are usually quenched under an air press.

Dr. Hoffman: The information I was trying to get is whether or not, so far as the cutting efficiency of the tool is concerned, one cooled in air showed any better cutting results or efficiency than one cooled in the air blast or one in oil and the other in the air blast.

Mr. d'Arcambal: I don't know, but I really do not believe you would find any difference. It is not so much the rate of cooling as it is the temperature of quenching, that is, the temperature the tool receives before being quenched.

Dr. Hoffman: You don't think there would be any difference, then?

Mr. d'Arcambal: I would hesitate to say so, because we have never conducted comparative tests, but from the theoretical standpoint I see no reason why there would be a difference.

Mr. French: I would like to refer to what Mr. Spalding has said and add also one item to Mr. Strauss' reply. Our tests show that when we have definite working conditions, the speed variation has a marked effect on performance. In the Taylor test the speed is the variable. I would like to know, or have Mr. Spalding give some detailed data as to whether we are really getting any better information when speed is varied to produce more uniform results. If speed changes have such a large effect upon the performance and the speed is varied in the Taylor tests, even though we get uniformity of results, do they really mean any more from the standpoint of the purchase of high-speed steel than comparisons of endurance? I would like to mention again while this discussion has tended toward a comparison of Taylor tests and the breakdown test, we had no idea originally of entering into that. We are simply accepting a test which has been used and examining it for a specific purpose.

Mr. Parker: In reference to the first point in the summary of the authors, I might say that several years ago a breakdown test was conducted in which about six or seven brands of high-speed steel were tried. This breakdown test was run wet, not dry. Steels A, and B, which were first and second in the breakdown test, were then taken and put on test in the shop. Twelve sizes of high-speed of brand A and brand B were taken, and these sizes ranged from quarter inch square to inch and a half by inch, six tools of each size were made and put on production work. The materials cut ranged from soft gray iron through screw stock, up to heat-treated alloy steel of high physical properties. There were ten grinds taken on each of the six tools, and at the end of the test the results were averaged. In every test of the twelve, in which there were sixty grinds, that is, six tools and ten grinds, brand A, which was high in the competitive test, was high in the shop test. And there was some variation, that is, if we take it for granted A was higher than B in the breakdown, say by fifteen per cent, that didn't always follow all down the line. In some cases the superiority of A was more marked than B, and sometimes the difference was not quite so much, but in every case brand A was superior to brand B. Brand A was of the low tungsten, high vanadium type, and brand B was of the high tungsten, low vanadium type.

Chairman Johnson: Our time is getting short, and we will not be able to use any more time for the discussion of this paper.

The next paper, I might say, is right in line with this subject. It is entitled "Carbide Segregation in High-Speed Steel," and will be presented by Col. A. E. White, director of engineering research of the University of Michigan.

Col. A. E. White then presented his paper as published in the January, 1923, issue of TRANSACTIONS.

Chairman Johnson: Gentlemen, you have heard Col. White's appeal for somebody to chase the nigger out of the steel pile. We all realize the immense importance of solving this problem. If somebody has solved it, they may hesitate a little about describing the method, and then again they may not. Are there any suggestions? I think Col. White intended this paper more, as an appeal to intensify research on this subject. But the prize is high enough that I think all concerned are very intensively engaged on the topic as much as their time permits and their research equipment during these times will justify. Are there any comments?

Mr. Muehlemeyer: Col. White's able paper has impressed me because he touched upon a subject that has been a sore spot with the users of high grade steels, especially high speed steel. I had occasion to study European practice some two years ago and as I had heard much rumor of the superiority of European practice to ours I was naturally anxious to see for myself. If European mill practice is capable of producing results superior to ours I failed to see it. Attempts have been made to overcome excessive segregation, which is as much of a drawback there as it is here, by centrifugal casting. This has not been successful as yet. It was also attempted to reduce segregation by casting flat ingots and splitting them afterwards. However, this resulted only in shifting the segregated area. There is no need to enumerate all the ways and means which have been tried to control segregation, suffice to say that it is

still a factor to be reckoned with. From the standpoint of the steel user there is only one way to get around the effects of excessive segregation, which is practiced in Europe as well as here, and that is more thorough inspection of material before shipment from the mill.

Mr. Curran: I fail to see where a diligent inspection will help in eliminating that trouble if they cannot eliminate it in the mill. For instance, if they are going to have 100 per cent segregation, I don't see where they are going to get away from it by inspection. I have noticed, however, that in two papers on the manufacture and treatment of high speed steel published in England in the last three or four years, both by mill men, that they emphasized the elimination of this carbide and tungstide segregation, and both insisted that it is absolutely unnecessary and undesirable. They didn't say how to get away from it though.

All of our experience with domestic high-speed steels indicate that when the size of the bar goes over two inches in diameter it is pretty certain that the structure will show very complete networks of these carbide and tungstide segregations.

Chairman Johnson: One practical aid in this matter, although not from the steel maker's standpoint, but from the customer's standpoint, is a method of cutting of sections, forging of these from a thicker size to a thinner size, cutting a circle from a round or a square from a square piece of a thicker size and getting a good forging to a thinner size. That is used by some with excellent results. That, of course, is after the steel is made and hasn't solved the problem from the melting end at all.

If there are no further remarks, we will take up the next paper by J. V. Emmons, metallurgist with the Cleveland Twist Drill Co., entitled "The Effect of Structure Upon the Machining of Tool Steel."

Mr. Emmons: I am not going to read this paper to you in detail, because it is published on page 1100 of September, 1922 TRANSACTIONS, which you now have in your hands. I will read a few notes and they will give the summary, and we will have the rest of the time for discussion and the asking of questions. (Reads notes)

Chairman Johnson: Before taking up a general discussion, we have this discussion mailed to us by Mr. B. H. DeLong, metallurgist of the Carpenter Steel Co., which I will read as an adjunct to what Mr. Emmons has said.

Mr. DeLong's Discussion

The writer has read with much interest Mr. Emmon's paper as it appears in the September, 1922, issue of the TRANSACTIONS of the Society, and wishes to congratulate the author upon the thoroughness with which this investigation has been carried out. It is interesting to note that he has a good word to say for lamellar pearlite in annealed carbon tool steel, for many of the specifications now written by tool steel users specify that the material must be free from this constituent.

It appears, however, that the value of the paper would have been increased, both from a scientific and from a practical standpoint had details been given of the practice employed in each operation. Types of machines and tools used, speeds at which the metal is cut or worked, size of steel used, etc., are some of the factors that have a

great influence uon the suitability of tool steel for a particular type of machining, as illustrated by the following experiences:

1.—Customer "A" purchases annealed carbon steel bars for the manufacture of cones in ball bearings. Two sizes are used, namely, 1¾ inches in diameter and 1⅜ inches in diameter. Cones from both sizes are turned upon automatic machines. The 1¾-inch diameter is annealed by the steel maker to show a Brinell hardness of about 180 and a scleroscope hardness of 28 to 31. The 1⅜-inch diameter is annealed to show a Brinell hardness of about 160 and a scleroscope hardness of 25 to 28. The micro-structure of each of these sizes varies with the hardness, as illustrated by the author of the paper, but the customer secures the highest possible production from each size only when within the hardness limits specified above.

2.—Steels for Taps—There is a very wide difference of opinion among the manufacturers of taps as to the degree of hardness of annealed steel which will result in most economical production. The Brinell limits specified upon orders for this material range from a maximum of 160 in one case to a minimum hardness of 200 in another case. Various Brinell limits between these two extremes are most often used. Each customer produces taps upon automatic machines, and the requirements of the finished tool as to surface, etc., are the same. Obviously steel having a maximum Brinell hardness of 160 could not have the same structure as steel with a minimum Brinell hardness of 200.

3.—Purchasers of annealed chromium steel for ball bearings specify Brinell hardness requirements varying widely. A list of specifications which the writer has in his files shows the following:

Customer "A"—Maximum Brinell hardness of 170 (Maximum 160 preferred).

Customer "B"—Brinell 160 to 180.

Customer "C"—Brinell 180 to 200.

All this material is used for the manufacture of ball bearing races and is hot-rolled annealed steel. Parts are machined in every case in automatic machines. Each customer is, of course, interested in getting the most economical production from their equipment and finds the Brinell hardness limits set give them the required results.

The writer agrees with the author of the paper that where the quantity of steel involved justifies the expense it is possible to select the most suitable structure for any particular operation with great exactness. He wishes to emphasize the fact, however, that the suitable structure and hardness for the same type of machining will vary greatly in different shops. Care should, therefore, be used not to generalize from the results secured in investigating one type of operation under one particular set of machining conditions.

Chairman Johnson: Gentlemen, is there any discussion on this?

Dr. Mathews: I would like to ask a question or two upon points which I think the paper doesn't make clear. Does this paper deal only with hypereutectoid and carbon tool steels?

Mr. Emmons: Yes, this paper is confined exclusively to hypereutectoid steel and carbon tool steels.

Dr. Mathews: What relation has been found between the best

structure for machining and the best structure for the tool as finally hardened?

Mr. Emmons: (Answering). I would say that the best structure for machining and the structure for producing the best hardened tool, roughly does coincide; that is, both demand in the hypereutectoid steel that cementite segregations and the relics of partially broken cementite network be eliminated so far as possible. Both of them require that the grain size be maintained small. After those two items have been taken care of I would say that the difference in the hardened tool which has been made from what we would call the completely spheroidized structure, and one in which there remains a trace of pearlite, is quite small. There is a difference, however, which might be brought out at this point. If the process of the coalescence or of the gathering together of the cementite into large particles has been carried to such an extent that the round cementite particles are of large size, it then becomes necessary in the hardening operation to allow a longer time at the hardening heat in order to permit the proper solution of these larger globules of cementite. If sufficient time is not allowed, the cementite will not go into solution to produce the maximum hardening effect.

Mr. d'Arcambal: Mr. Emmons' excellent paper on the effect of structure upon the machining of tool steel is the first paper of its kind that the speaker has ever seen published, and fills a much needed want. I have often heard it said that tool steel of a certain Brinell hardness and microstructure is found to be ideal for machining in one plant, but gives trouble to some other concern manufacturing the same class of tools. This statement is verified by comparing the tool steel structure, Fig. 13, and the Brinell hardness range considered ideal for turning, milling, threading, etc., by Mr. Emmons with the structure and hardness of a steel of a similar analysis which is considered ideal by the company I represent.

Experiments conducted some time ago by the Pratt & Whitney Co. indicated that a tool showing a Brinell hardness of from 160 to 190, (170 Brinell preferred, and with the cementite all in the spheroidal form) was the best suited for the different operations such as turning, fluting, threading, etc. Mr. Emmons states that tool steel coming within this range is very difficult to thread and mill at his plant, but we have machined thousands of tons of steel within these Brinell limits, and experienced no difficulty whatsoever with the machineability of the material. Mr. Emmons makes no reference as to the previous treatment the material has received before annealing. My remarks are confined to hot rolled tool steel which has been pipe annealed by the steel mill after the final cogging operation, but I believe that Mr. Emmons' company anneal all of their own tool steel. The finishing temperature the steel has received at the mill also has a great effect upon the resultant microstructure of the annealed material.

Mr. Emmons states that the hardness of the material containing 25 per cent pearlite, as shown in Fig. 13, runs from 190 to 230 Brinell. Our material showing this microstructure has a Brinell hardness of from 180 to 190. Apparently the previous treatment received by the material before annealing is the cause of this difference.

It would also add to the value of his paper if Mr. Emmons would

have gone more into detail as to the different methods of threading referred to. Single point or lathe threading, die threading, chaser threading, hob threading and threading with a thread milling cutter are all methods commonly used throughout the industry. A few days ago we prepared some test pieces of about 1.15 per cent carbon hot rolled tool steel taken from annealed bars of different Brinell hardness. These samples were turned, threaded in two different ways, then fluted, and the slide will show you the results obtained. You will note that as far as turning is concerned, the softer the steel, the better. For the fluting operation, however, material 160 Brinell and under is too soft, and material 195 Brinell and higher is too hard. Steel with a Brinell of from 170 to 187 flutes satisfactorily.

For lathe threading or single point threading, using a spring tool holder, there is no choice between the finish on material running as low in Brinell as 153 or as high as 228. The operator, however, stated that the samples 187 Brinell and higher seemed to be a trifle hard. No burrs were thrown up by the softer steel nor did the tool dig in.

Threading by means of a thread milling cutter, the only sample which showed a rough thread was the material Brinelling 228. The sample specimens referred to in the discussion will be placed on the table for the inspection of all interested in the same.

I would be very much interested in knowing whether Mr. Emmons has ever conducted tests to show the relation between machining qualities and cutting efficiency.

Chairman Johnson: I think we will pass on unless somebody is very anxious to discuss this paper further, and take up the next paper, "A Metallographic Study of Hollow Drill Steel," by Dr. N. B. Hoffman, metallurgist with the Colonial Steel Co. of Pittsburgh.

Dr. Hoffman then presented his paper as it was later published in the January, 1923 issue of TRANSACTIONS.

Chairman Johnson: As our time is getting very limited and many of you wish to attend the ceremonies to be held in Wyandotte this afternoon, we must hasten on to the next paper entitled, "Deterioration of Steel and Wrought Iron in Hot Gaseous Ammonia," by J. S. Vanick of the Bureau of Standards, Washington, D. C.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A DISCUSSION OF ROBERT G. GUTHRIE'S PAPER ENTITLED "THE USE OF VARIOUS KINDS OF LIGHT IN METALLOGRAPHY."

By Herman A. Holz

REFERRING to Robert G. Guthrie's paper on "The Use of Various Kinds of Light in Metallography," published in the April, 1923 issue of TRANSACTIONS, pages 710-719, I desire to make a few remarks, as it contains some statements which should not stand unchallenged on the records of the American Society for Steel Treating.

First of all, light is a substance and as such follows, more or less, the law of gravity. This theory, first offered by Einstein, has been fully proven by the recent investigations of the Lick Observatory.

The use of lightfilters (i.e., monochromatic light) which Mr. Guthrie claims to be imperative for obtaining good micrographs of high magnification becomes necessary only if objectives of poor quality are used. In the application of fully apochromatic objectives which are justly preferred by most up-to-date metallographists, the lightfilters are not at all necessary for perfect results.

As to the resolving power of objectives, immersion lenses of 1.60 N. A. are now available, using monobromnaphthalene ($n=1.66$) as immersion fluid. If ultraviolet light is used, only glycerine can serve as immersion fluid and the objectives must consist entirely of fused quartz.

The arc produced between magnesium wires has a wavelength of about 280 $\mu\mu$ and produces in many cases such a strong fluorescence that it is possible to focus the microscopic image quite sharply; the cadmium arc of 275 $\mu\mu$ wavelength has similar properties, but yields light of greater chromatic purity. A glycerine immersion objective with N. A. of 1.25 for white light has a relative resolving power of 2.50 if used with light of 275 $\mu\mu$ wavelength.

As to polarized light, its application to metallographic investigations is very valuable, but not in the manner indicated by Mr. Guthrie. In working with polarized light, the specimens should be highly polished, but not etched; the specimen is mounted in the center of a rotating stage and is rotated. No results of value can be obtained by means of an apparatus such as indicated in Fig. 7 of the paper. In the correct use of polarized light no plane glass illuminators or reflecting mirrors should be used, as these are polarizers themselves. No sharp images can ever be obtained by their use.

So far, valuable metallographic work by polarized light has been carried out only on vertical microscopic stands (not inverted), using the Le Chatelier prism illuminator and investigating polished, unetched

specimens mounted on an accurately centered rotating stage. As far as I can see, it cannot possibly be done in any other way if results of practical value are expected. By means of a very simple attachment, every metallurgical upright microscope stand can be made suitable for these investigations.

For photomicrography with polarized light, the achromatic objectives are useless, if an artificial source of light is used, on account of the focal differences otherwise compensated by lightfilters. Only the very best apochromatic objectives set in mountings free from stresses can be used, as every strain in the glass shows up clearly under polarized light. Autochrome plates can be applied to advantage to bring out the effect of the polarized light.

The micrographs Figs. 10 to 13 shown by Mr. Guthrie do not mean very much without explanation of how the magnifications were obtained. Apparent or so-called "empty" magnification by means of oculars or bellows extension has no value; this should not be called "magnification," but "enlargement." Mr. Guthrie states: "the photomicrographs speak for themselves and show of what value they are in the analysis of materials microscopically." This is expressed very diplomatically. I fail to hear these photomicrographs speak, but if Mr. Guthrie would have claimed that they show anything of value, I would have disagreed with him. The micrograph Fig. 13 of 11,000 diameters magnification does not and cannot show a bit more than I can see by taking a pocket magnifier and holding it over picture Fig. 10.

Referring to the closing sentence of Mr. Guthrie's paper, a micrograph such as he mentions can have a practical value solely to people who are very near-sighted. A man with normal eyesight cannot obtain any more information from Fig. 13 than from Fig. 10.

Mr. Guthrie's Reply to Mr. Holz's Discussion

To the Editor:

Referring to the criticisms offered by Herman A. Holz, I wish to state that his communication sounds much as though he had something to sell. It would hardly be necessary to answer his letter if it were not for the fact that he seems to be mixed up on a few points, and no doubt a certain amount of space is allotted to this sort of thing anyway.

In the first place, he mentions light as being a substance, subject to the law of gravity, and as having been offered first as a theory by Einstein, and also mentions the recent investigation of the Lick observatory which appeared in the newspapers not so long ago. The only reason I can see for this first paragraph is that he evidently is attacking the so-called undulatory theory of light, which I mentioned as being the commonly accepted one. The theory that light is a substance was not first offered by Einstein; but be that as it may, there is hardly any doubt that light is a substance the same as electricity is also a substance. However, that has nothing whatsoever to do with the undulatory theory of the propagation of light. The undulatory theory, as has been previously stated, is only the theory of propagation and not the theory of what light is. It is granted that light is a substance, but it is further stated that it is propagated as wave motion.

His next paragraph on the use of light filters assumes, for some reason or other, that the objectives used were of poor quality. As regards this, I

would prefer to refer him to E. Leitz, Inc., of New York. He further assumes that these objectives were achromatic, whereas it happens that they are the very best apochromatic objectives manufactured by E. Leitz, Inc.

Regarding emersion lenses of 1.6 numerical aperture as being available, I should say that I would be very glad to receive literature on them, short mounted and corrected for uncovered objects.

His next paragraph, regarding short wave lengths of light, speaks of the magnesium arc; however, I don't know of any way of applying this method of illumination to metallography, and as far as short wave lengths of light are concerned, it is entirely possible to get even shorter wave lengths than he mentions here by the use of the water cooled tungsten arc.

His next paragraph seems to contradict itself in such a way that I don't know what he means. Furthermore, I don't know how he knows that "No results of value can be obtained by means of an apparatus such as indicated in Fig. 7 of the paper." This work was done merely to find out what could be done in that connection, and I am frank to admit that I don't know of what value it might be to some people, whereas to a majority of people it possibly would be of no value at all, and on the other hand some one person might get a great deal of value out of it. In this paragraph he also states that it is only correct to use polarized light on highly polished specimens. I have examined a great many highly polished specimens before etching, and see the same thing in all of them, namely, a bright, meaningless film; inasmuch as the polishing actually is not one of abrasion but is rather one of wiping or smearing the surface over with a fine film of the softer constituents, I cannot understand just how any value can be obtained from this method. He also goes on to state that "In the correct use of polarized light, no plain glass illuminators or reflecting mirrors should be used, as these are polarizers themselves." I agree, as I think everyone else does, with the statement that mirrors are polarizers; as far as that goes, any mirrored surface may be made to polarize a beam of light.

In the next paragraph, he speaks of a vertical microscope with a LeChatelier prism illuminator as the correct apparatus for the use of polarized light or reflecting surfaces. This seems a little mixed up to me, as he mentions in the paragraph previous that no plain glass mirror or reflecting mirrors should be used; however, it is entirely possible to obtain polarized light in the apparatus mentioned in Fig. 7, providing the arm of the inverted microscope, which carries the ocular, is at right angles to the reflecting mirror beneath the vertical illuminator. Any one having this apparatus may prove for themselves that the light is polarized by placing an analyzer over the ocular and slowly rotating it. If the reflected beam is not polarized, it would not react to the analyzer and notwithstanding the previous arguments, it is entirely possible to produce polarized light with either the vertical or inverted microscope. I will, however, agree with Mr. Holz in the fact that in polarized light one should have a perfectly centered rotating stage, and I would further say that in my opinion, humble as it is, all metallographic microscopes should be equipped with a perfectly centered rotating stage. The manufacturers of this sort of equipment would do very well to equip all their metallographic microscopes with the very best and accurate rotary stage that it is practical to build.

The next of Mr. Holz's communication, which deals with high magnification, consists more or less of individual opinion and he is very welcome to them if he so chooses. I did not state that the micrographs, Figs. 10 to 13,

mean any more than they would if taken with the same objectives, but with a short bellows extension. It is very desirable in some classes of work to enlarge the initial magnification considerably that the individual constituents may be more apparent than they are at a lower magnification. It is entirely true, and follows in very natural consequence, that you cannot possibly see anything in a micrograph that is not resolved by the objective, and that for all practical purposes it is not well to go over 1500 diameters with an oil emersion objective of 1.32 numerical aperture. The photomicrographs at 11,000 diameters were obtained merely by the very simple method of using a full camera bellows extension. I might say further that the paper presented before the American Society for Steel Treating was not given with the thought that it presented any new or radical departures from any of the existing methods nor was it a paper intended as an explanation or a complete dissertation on the physics of light, nor on the science of optics. However, Mr. Holz speaks of a great many things that I would like to see done, such as some photomicrographs with an objective of 1.6 numerical aperture using the magnesium arc. It is all very well to mention these things, as regarding what can be done, or what one thinks might be done, but it is somewhat of a different proposition to do them and publish the results so that all may see and benefit thereby.

AUTHOR'S CORRECTION TO DISCUSSION FOLLOWING PAPER ENTITLED "ELECTRIC FURNACE MELTING PRACTICE"

REFERRING to the discussion following the paper entitled "Electric Furnace Melting Practice" by E. G. Stedman, as published in the April, 1923 issue of TRANSACTIONS, page 747, the author has directed our attention to the fact that an error existed in the original manuscript. The twelfth line from the bottom of page 747 should read:

Mr. Stedman: It is cheaper to produce open-hearth, naturally.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 82. *What analysis steel is most suitable for punching out hot work on upsetter in drop forge shop?*

QUESTION NO. 83. *In annealing high carbon tool steel in an open fire furnace 6′ x 12′ is it likely that sulphur would be imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around* 1.50 *to* 2.00 *per cent?*

QUESTION NO. 84. *What is the effect on the steel being forged, through the use of high velocity blows during drop forging?*

QUESTION NO. 85. *What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 67. *What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?*

ANSWER. By Clifford B. Bellis, metallurgist, the Bellis Heat Treating Co., New Haven, Conn.

The specific heat of brine is greater than that of water, and so the steel is cooled faster. The ability of a liquid to transmit heat depends principally on its fluidity and its specific heat.

As the quenching medium moves past the steel by convection, heat passes from the steel to the contiguous portion of the medium. The rate of this flow depends upon the temperature difference between these two. If the specific heat of the medium is high, the portion contiguous to the steel will rise only slightly in temperature for a given quantity of heat transferred. Therefore, the temperature difference between the steel and the part of the

bath in its immediate vicinity will be greater than if the specific heat of the medium were lower.

A less important reason for the "effectiveness" of a brine quench is that its boiling point is higher and therefore the steam blanket around the steel being quenched is not so great.

QUESTION NO. 69. Is sulphur up to 0.10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 per cent carbon acid open-hearth steel and an alloy steel of either 3.5 per cent nickel or 1.5 per cent nickel and 0.50 per cent chromium neither heat treated?

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO. 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 76. Why are cold drawn carbon and high-speed steels sometimes supplied with a copper coating? Does this coating affect the steel in any way, or is it merely a lubricating agent in the drawing process? Is it necessary or desirable to remove the coating before hardening?

QUESTION NO. 78. Does microscopic or macroscopic examination of a fatigue failure indicate, even approximately, how long the crack has been forming, or how many times the stress was applied during the growth of the crack?

ANSWER. It is not probable that any microscopic or macroscopic tests will ever indicate the duration of fatigue stresses. An example may be given of a case of fatigue failure in a crankshaft of an automobile engine which had been applied to an ice-cutting machine. In the first year, the company had experienced fifty per cent of failures, due to the breaking off of the fly-wheel end. A specimen of the part broken off next to the fly-wheel end was

given a macroscopic examination, pickled and hot etched to observe if there were any laps or seams visible, and also to study the direction of the flow of the metal. The observation showed that there were no laps or seams and the direction of the flow was satisfactory. The examination further disclosed three entirely separate fatigue fissures which extended nearly half way through the cheek of that particular throw of the crankshaft pin. The actual break had occurred at the shoulder between the cheek and bearing pin. These three fatigue breaks or fissures which had not proceeded to a final fracture were observed very plainly by the microscope. They were located in one-half of the throw, and the throw was found to be split axially or longitudinally. The other half was marked very carefully to indicate where the fatigue fractures were, and the specimens were polished and examined with a microscope. The result was that the crack could not be found.

If the parts were allowed to stand for a while after being polished, a small amount of oil would ooze out of the fissure and form in very small drops and would outline the position and extent of the fissure when a magnification of X 500 was used.

Under the circumstances if the fissure cannot be seen microscopically without some aid, such as the oil that was in the crack, it is believed that there is not much chance of measuring the length of time, or the possible life of the fatigue break by this means.

QUESTION NO. 79. *Does the apparent grain size of a fatigue fracture vary with the load applied to cause failure, or with the fatigue strength of the material?*

ANSWER. In breaking certain parts by repeated blow where the fracture can be traced almost blow by blow, after the crack has once been started, it can be easily seen that it proceeded by steps of sometimes greater and sometimes smaller length, according to the weight of the blow. It is believed that the roughness of the surface is due to the intensity of the stress to which it is subjected. In observing the breakage of rolls where the fracture takes place starting out through the fillet, where the neck joins the body of the roll, it is not an infrequent occurrence in cold rolling to have the final rupture disclose the fact that there was a small crack existing for some time before, as shown by the discoloration. In that case very little difference in the degree of roughness of the surface can be seen, but where pieces are broken by repeated blows of a hammer or sledge, some of which will be considerably heavier than others, the difference reflected in the length of the steps in the break can be detected.

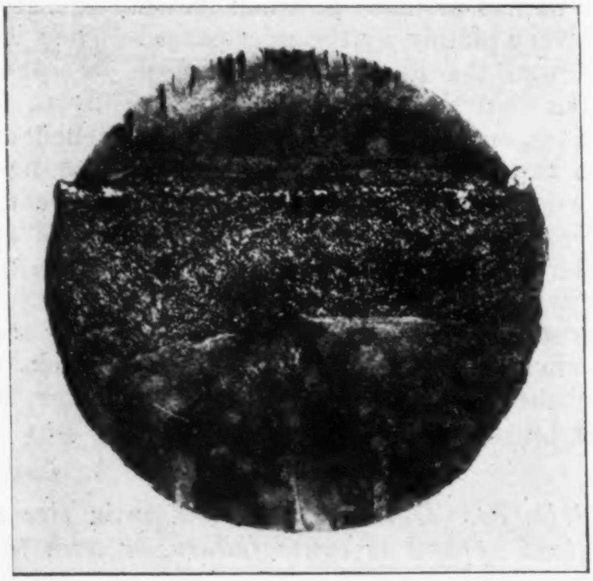
QUESTION NO. 80. *Does a banded fatigue fracture indicate interruptions in the growth of the crack?*

ANSWER. It is probable that the banded fatigue fracture indicates interruptions in growth of the crack, either due to variable loading or alternating loading or arrested growth of the crack resulting from much lighter loading.

QUESTION NO. 81. *How can you distinguish between a fatigue failure in ductile metal and a sudden failure in a metal which was brittle at the time of rupture?*

ANSWER. The fatigue failure can be easily distinguished from the

sudden fracture inasmuch as the surface of the fatigue break usually has a silky appearance, while the surface of the sudden break appears jagged and crystalline. Frequently the fractured surface of a fatigue failure will show a combination of two or more types of fractures as is shown in the accompanying illustration. The upper and lower zones of this fracture have the silky appearance of the progressive fatigue fracture while the band across



the center zone is crystalline in appearance, indicating a sudden fracture. This photograph was taken of an automobile steering knuckle which had failed in service. Inasmuch as the principal stresses were in a vertical plane the narrow band across the center was formed in the horizontal direction or normal to the stresses. Usually a brittle metal will break off suddenly resulting in a sparkling crystalline fracture whereas the more ductile metal when subjected to fatigue strains will fail with the silky appearance. This silky appearance of the fracture is the result of the progressive alternating bending and rubbing of the crack walls against each other.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

DIFFICULTIES IN HARDENING HIGH-SPEED STEEL. By O. G. Simmons, in *Machinery,* April, 1923, page 627.

In this article the author tells how high-speed steel specimens that would not harden when heated to the specified temperatures in the presence of certain gases would harden by quenching after being heated in an open coke fire, coal fire, a semi-muffle gas furnace or an oil-fired furnace. The author explains the experiments fully, giving several illustrations.

CORROSION OF RUSTPROOFED IRON AND STEEL. By W. P. Wood, Assistant Professor of Metallurgical Engineering, University of Michigan, in *Chemical and Metallurgical Engineering,* April 30, 1923, page 769.

This article states that galvanizing is the best method of protection against rusting when the specimen is immersed in fresh water saturated with oxygen. It further states that the low-carbon steel and the uncoated iron corrode at about equal rates under these conditions.

DROP FORGING PRACTICE. By Leslie Aitchison, in *Forging and Heat Treating*, April, 1923, page 176.

The above was a lecture delivered before the Association of Drop Forgers and Stampers in Birmingham, England, on November 22, 1922. It discusses the principles which determine the size of the bar or billet for use in manufacturing drop forgings. The preliminary forging operations are also discussed in detail.

THE METALLURGICAL MICROSCOPE. By W. M. Mitchell, in *Forging and Heat Treating*, February, 1923, page 106.

This is the second part of an article dealing with the metallurgical microscope which includes a discussion of the various types of illumination and various phases of photomicrography.

The first part dealt with the uses and limitations of lenses.

CASTING IRON IN LONG-LIFE MOLDS. By Richard Moldenke, in *Iron Trade Review*, May 3, 1923, page 1299.

In this article the author tells how the output can be increased by machines equipped with mechanical features; everything being automatic but the pouring operation.

CRITICAL TEMPERATURES FOR ANNEALING GRAY IRON. By Dr. Ing Emil Schuz, *Stahl und Eisen*, September 18, 1922.

The above article discusses the procedure for determining the critical temperature for annealing gray iron, and shows the influence of phosphorus and graphite on hardness. It further shows the importance of pearlite and gives examples of the cementite decomposition.

HEAT CONTROLS IRON STRUCTURE. By E. Adamson, in *Iron Trade Review*, April 19, 1923, page 1156.

This article states that carbon is the main factor in pig iron and is controlled by the physical rather than by the chemical properties. It also states that metallurgists are accepting structure tests rather than the chemical composition. In this article Moissan's work on carbon in pig iron is described.

RECENT ELECTRIC FURNACE DEVELOPMENTS. By Edward T. Moore, Electrical Engineer, Halcomb Steel Co., Syracuse, N. Y., in *Forging and Heat Treating*, April, 1923, page 187.

This article shows that the great demand for any method or device helps to produce development, and this has been especially true with the electric furnace. It describes these developments in detail.

CUTTING DOUBLE HELICAL OR HERRINGBONE GEARS. By Franklin D. Jones, in *Machinery*, April, 1923, page 613.

In this article the author tells how the duplex type of planer may be used for cutting herringbone gears of large pitch. He also shows the application of gear shapers and the end-milling process for cutting these gears.

AUTOMATIC FEEDING DEVICE FOR HIGH-SPEED DRILLING. By Charles E. Bernitt, in *Machinery*, April, 1923, page 621.

This article describes in detail the automatic feeding machine for high-speed drilling, giving illustrations showing the respective parts, and how they are employed.

Reviews of Recent Patents

1,442,213. Metal-drawing Apparatus and Method. Louis H. Brinkman, Glen Ridge, N. J., assignor, by mesne assignments, to General Seamless Tube Co., Bloomfield, N. J., a corporation of Delaware.

This patent relates to a metal-drawing apparatus, which consists of a mandrel for metal drawing, a refractory head, a tube of less refractory material, heat insulation on said tube, a member of less refractory metal than said head, said member having screw threaded connections with head and tube and a passage for cooling fluid adapted to prevent impairment of the threads engaging with said head, said fluid being prevented from coming in contact with said head, and a pipe for cooling fluid extending within said tube.

1,443,580. Electric Furnace. George M. Little, Pittsburgh, Pa., assignor to Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent refers to an electric furnace comprised of a furnace chamber, and terminal electrodes operatively engaging said resistor and projecting through a wall of said furnace, of combined contact terminals and cooling means secured to the outer ends of said electrodes and a stationary cooling means surrounding said electrodes and located intermediate to said resistor and said terminals.

1,443,581. Electric-Resistance Tabular Furnace. George M. Little, Pittsburgh, Pa., assignor to Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

The above relates to an electric furnace comprising a heater tube of resistance material divided into sections, a heat-storing means around the tube, compression means to hold the sections together, and means for conducting an electrical current to and from the heater tube.

1,443,816. Electric Furnace. Francis A. J. Fitzgerald, Niagara Falls, N. Y., assignor to Buffalo Apparatus Corp., Buffalo, a corporation of New York.

This refers to an electric melting furnace comprising a furnace chamber oppositely arranged electrodes passing through the walls of the chamber, a holder for each electrode, a right hand operating screw rotatably mounted below one electrode, a left hand operating screw rotatably mounted below the other electrode, an operating arm for connecting each of the screws with one of the electrodes, an operating shaft and means for connecting the shaft with the operating screws.

1,444,062. Process for Producing Stainless Steel. Frank D. Carney, New York city.

This invention relates to a method for making stainless steel which comprises the adding of ferrochrome to a steel and maintaining the melt sufficiently hot to cause a change of the relative affinities of oxygen for carbon and chrominum and thereby cause the carbon to oxidize before the chrominum.

1,444,228. Scleroscope. Gottfried Wirrer, Plainfield, N. J., and Arlington Clinton Moyer, Allentown, Pa., assignor to International Motor Co., New York, a corporation of Delaware.

The above relates to the combination of a machine for testing the hardness of materials, a hammer, an open ended tube in which the hammer moves, devices for supporting the hammer releasably in raised position in said tube including a hook engageable

with the hammer, a cylinder carried on the tube and communicating therewith through an air port, a manually operable piston reciprocable in the cylinder and means engageable by the piston and with the hook for moving the latter out of engagement with the hammer, said piston being adapted to overrun said air port before release of the hammer to place the tube in communication with the atmosphere.

1,444,567. Method of and Apparatus for Testing Materials. Frederick W. Speer, Jr., Oakmont, Pa., assignor to the Koppers Co., Pittsburgh, Pa., a corporation of Pennsylvania.

The above relates to an apparatus for testing materials which comprises a refractory container adapted to contain a sample of the material to be tested, said container having a movable element adapted to be actuated by the expansion or contraction of said sample, and heating means whereby that portion of the container containing the sample may be heated, the heating means and the container being movable relatively to each other to progressively heat the sample.

1,444,584. Electric Furnace Having Resistor Dome. Guilliam H. Clamer, Atlantic City, N. J., and James R. Wyatt, Camden, N. J., assignors to the Ajax Metal Co., Philadelphia, a corporation of Pennsylvania.

This patent refers to an inductive electric furnace, comprising a chamber having an annular electrical conductor with which the pool is adapted to engage at the bottom and which is adapted to overlie the pool at the top in the form of a dome, and a transformer therefor, having one leg passing through the electrical conductor.

1,444,606. Scleroscope. Richard Herrmann, Berlin, Germany, assignor to Schuchardt & Schutte, Berlin, Germany, a firm.

This invention refers to a scleroscope, the combination with a gravity actuated hammer, of a slotted prismatic guide therefor, closed at the open side by a strip of transparent material; and a driver device adapted to return the hammer to its starting position, the driver being carried through a corner of the prismatic guide in manner such that a slot of said guide, intended for its passage, does not extend into the line of contact of the guide with the hammer.

1,444,891. Method for Making Acid-Proof Alloys. Richard Walter, Dusseldorf, Germany.

The method of making an acid-proof alloy is described in this patent. The alloy contains a relatively high silicon content, and over 0.65 per cent of carbon. The process consists of melting down the ingredients and pouring the molten bath at a temperature only slightly above the fusing point of the alloy.

1,444,939. Electric Furnace. Thomas A. Reid, Pittsburgh, assignor to the Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent describes an electric heating furnace. The refractory walls for this furnace are provided with a plurality of spaced-apart relatively narrow, elongated refractory members extending beyond the inner surface of the chamber walls, each having a plurality of spaced-apart transversely extending slots of substantially L-shape adjacent to the inner surface thereof. A plurality of end-connected convolutions of relatively heavy and self-supporting-resistor material located in said slots and extending openly between said refractory members, are provided.

1,444,948. Electric Furnace. Cranston H. Carpenter, Wilkinsburg, Pa., assignor to Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent describes an electric furnace, the combination with a refractory casing, of a muffle of refractory electrical-conducting material in said casing and hoppers in said casing on opposite sides of the muffle. Solid carbonaceous terminal electrodes extending into said hoppers are provided. A mass of electrical-conducting granular material in each of said hoppers adapted to electrically connect said electrodes and said muffle and to permit the current to traverse the walls of said muffle. The said masses of granular material is in contact with the said muffle over a relatively small portion of its surface.

1,444,980. Electric Furnace. William E. Moore, Beaver Pa.; Herbert Franklin Alter, and Edward At Lee Hanff, Pittsburgh, and John Raymond Eckley, New Kensington, Pa., and Frank Wright, Newport, Ky., assignors to Pittsburgh Engineering Work, Pittsburgh, Pa., a corporation of Pennsylvania.

A patent describing a rocking type of electric melting furnace comprising a shell having a tapping spout. Rockers or trunnions are attached to the shell at diametrically opposite points and at right angles to the tapping spout. These rockers are arranged with the rolling surface above the floor line and so formed as to make the stream issuing from the tapping spout travel in paths which meet the receiving vessel at substantially the same point.

1,445,220. Furnace. Charles L. Lee, Dayton, O., assignor to General Motors Research Corp., Dayton, O., a corporation of Delaware.

This patent describes a furnace, comprising a casing, closure means for one end thereof, the closure means being provided with a central opening with a means for centering and securing the work piece within said casing and over said opening a closure. A closure for the other end of said casing is provided and a means for supplying a heating medium through said opening to and within the work piece.

1,445,253. Resistance Alloy. John H. White, Cranford, N. J., assignor to Western Electric Co., Inc., New York city a corporation of New York.

Describing a ferronickel alloy containing more than 60 per cent nickel, in which a portion of the iron is replaced by a material having the properties of tantalum.

1,446,153. Method of Making High-Speed Steel. William B. Brookfield, Syracuse, N. Y.

This patent describes a method of making "high-speed" steel, consisting in subjecting the ingredient element "en masse" to continuous heat sufficient to produce a maximum degree of homogeneity under that heat and afterward resubjecting the product thus formed to another melting heat sufficient to cause a further and more uniform assimilation of said ingredient elements and, therefor, to increase the homogeneity without the addition of other materials.

1,446,497. Alloy. Hugh S. Foote, Pittsburgh, Pa., assignor to Standard Chemical Co., Pittsburgh, Pa.

This patent relates to an alloy consisting of steel having alloyed herewith silicon, manganese, uranium and vanadium in the proportions within the range substantially as specified.

1,446,981. Pouring Mechanism for Refractory Furnaces. Oliver J. Marshick and Edwin L. Crosby, Detroit, Mich.

This invention relates to a machine in combination with a rotatable furnace drum, means on one side thereof adapted to co-operate with a removable external supporting members in constituting a laterally disposed turning axis, and means for lifting upon the opposite side of the drum, whereby the elevation thereof is through an arc whose center is located coaxially with said turning axis.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday, Wing E., 15th Floor General Motors building.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Fdiday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The contest is drawing to a close, yet there remains sufficient time for considerable readjustment as is evidenced by the tremendous strides that have been made by a few of the chapters in the past few weeks. It is interesting to note that two chapters have reached the 100 per cent increase in membership, Tri City and South Bend.

A part of the increase for Tri City has been due to the energetic work of the executive committee in securing 13 new sustaining memberships. Besides putting their treasury in a healthy condition, it has put them away ahead in the contest.

Six chapters have had a 50 per cent increase in membership. The following arrangement of the chapters shows the percentage of net increase of

new members based on the number of members each chapter had on September 1, 1922:

		Per Cent			Per Cent			Per Cent
1.	Tri City	149.0	10.	Syracuse	43.7	19.	Indianapolis	19.7
2.	South Bend	100.0	11.	Lehigh Valley	38.9	20.	Chicago	17.9
3.	Cincinnati	94.5	12.	Schenectady	29.4	21.	Washington	17.5
4.	Detroit	73.8	13.	Rockford	29.2	22.	Pittsburgh	16.1
5.	North West	69.5	14.	Hartford	27.8	23.	Providence	13.2
6.	Philadelphia	57.7	15.	Buffalo	25.0	24.	St. Louis	10.5
7.	Milwaukee	46.7	16.	Toronto	25.0	25.	Springfield	10.3
8.	New Haven	45.5	17.	Cleveland	24.8	26.	Worcester	8.9
9.	Boston	44.0	18.	New York	24.1	27.	Rochester	4.8

Attendance At April Meetings

Eighteen chapters reported attendance at April meetings. No attendance report was received from Boston, Chicago, Buffalo, Lehigh Valley, Pittsburgh, Providence, Rochester, Schenectady and Worcester.

The following gives the percentage of attendance at April meetings. Chapters printed in CAPS show an increase in attendance over March meeting:

		Per Cent			Per Cent			Per Cent
1.	New Haven	70.0	7.	Springfield	36.4	13.	Cincinnati	29.4
2.	Tri City	64.5	8.	St. Louis	35.4	14.	Toronto	24.2
3.	Rockford	50.0	9.	North West	34.0	15.	Cleveland	23.7
4.	Syracuse	48.4	10.	Philadelphia	33.2	16.	Washington	22.7
5.	Hartford	45.7	11.	Milwaukee	32.6	17.	Detroit	19.4
6.	South Bend	47.6	12.	Indianapolis	31.2	18.	New York	16.2

Standing of the Chapters in the Contest

On the basis of 50 per cent for average attendance at meetings since December and 50 per cent for net increase in membership since September, the standing of the chapters on May 1 is as follows:

		Per Cent			Per Cent			Per Cent
1.	Tri City	100.2	8.	Philadelphia	43.2	15.	Cleveland	23.9
2.	South Bend	76.8	9.	Milwaukee	38.4	16.	Springfield	23.5
3.	Cincinnati	61.9	10.	Rockford	35.9	17.	St. Louis	21.2
4.	North West	53.4	11.	Providence	35.0	18.	Chicago	20.5
5.	New Haven	51.2	12.	Hartford	33.5	19.	New York	19.0
6.	Detroit	49.3	13.	Toronto	30.6	20.	Pittsburgh	15.9
7.	Syracuse	46.2	14.	Washington	24.5			

It is to be noted that Tri City, South Bend and Cincinnati are occupying the same positions held in the previous report, while North West has advanced from sixth position to fourth and New Haven has dropped from fourth position to fifth, while Detroit is occupying sixth position.

The percentage of increase in the membership of the Detroit chapter has been quite remarkable and probably denotes the most substantial growth in membership of any chapter, yet because it is the largest chapter in the society the number of those in attendance at the meetings have to be figured against the total membership which brings their percentage of attendance to a low figure, although they have remarkably fine and well attended meetings.

New Members

We have a much better report to make this month as to new members and that is due to the fact that the number of members dropped was much

smaller. There were 89 new members received into the society during the month, while the society suffered a loss of 39 members, 27 of whom were dropped for non-payment of dues and 10 resigned, making a net gain for the month of April of 52 members.

Based on the number of members in each chapter on May 1, the following shows the standing of the 27 chapters of the society. Those printed in CAPS have advanced their position while those that are in italics have a lower position than that occupied in the previous report:

1. Detroit	10. Tri City	19. *Rockford*
2. Chicago	11. *Syracuse*	20. Washington
3. Philadelphia	12. North West	21. Buffalo
4. Pittsburgh	13. *Lehigh Valley*	22. Providence
5. Cleveland	14. Cincinnati	23. *New Haven*
6. New York	15. *Worcester*	24. *Schenectady*
7. *Hartford	16. Indianapolis	25. Springfield
8. *Milwaukee	17. South Bend	26. Toronto
9. Boston	18. *St. Louis*	27. Rochester

*Tied

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held its regular monthly meeting on Thursday evening, May 10, at 8 p. m. at the Ohio Mechanics institute. The speaker for this evening was Arthur Townsend, chief chemist, Cleveland Twist Drill Co., Cleveland, who presented a very capable paper entitled "Practical Methods on the Inspection of Tool Steels," illustrated with stereopticon slides. Mr. Townsend having had considerable experience in the inspection of tool steels presented a very interesting and capable paper in which he outlined many of the defects which steels are likely to have. He illustrated his paper with some actual specimens showing some of the typical defects as well as typical satisfactory structures and included in his paper the discussion of the hardening of steels and their inspection by the fracture and macrographic methods. Mr. Townsend's paper was very well received and brought forth a very good and interesting discussion.

Prior to the paper of the evening the chapter held its annual business meeting at which time J. Culver Hartzell was re-elected chairman, Fred L. Martin was re-elected secretary-treasurer and J. H. Nead was elected vice-chairman. Dr. Hartzell read a long report on the activities of the Cincinnati chapter for the past year.

This meeting was one of the best attended meetings of the whole season.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held its annual meeting Friday evening, May 25, in the rooms of the Cleveland Engineering society, Hotel Winton, Cleveland. The program for this evening consisted of two papers, the first being presented by R. L. Sanford, director of the magnetic testing laboratories of the U. S. Bureau of Standards, entitled "Magnetic Analysis—A New Method in Metallography." In this paper the speaker outlined in considerable detail the development which has been made in the magnetic testing of materials pointing out its limitations as a routine method of inspection. A very interesting discussion followed

Mr. Sanford's paper which brought out many interesting points of information. The paper was well illustrated with stereopticon slides showing apparatus and curves obtained therefrom.

The second paper on the program was entitled "The Contour Measuring of Threads and Gear Teeth," presented by H. F. Kurtz, assisted by I. L. Nixon, both connected with the Bausch & Lomb Optical Co. Following the presentation of the paper which covered in considerable detail the various methods of obtaining accurate contours Messrs. Kurtz and Nixon gave a demonstration of the operation of the contour measuring apparatus as manufactured by the Bausch & Lomb Optical Co., as it is used in the examination of thread and gear contours. Specimens of threads and gears were placed in the machine and projected upon the screen so that the audience could see their actual contour and mesh.

As this was the annual meeting the officers for the ensuing year were elected. They are R. S. Archer, chairman; C. W. Simpson, vice chairman; D. M. Gurney, secretary-treasurer. Executive committee is as follows: W. F. Abel, J. V. Emmons, E. C. Bartlett, and H. M. Boylston.

Following the meeting a buffet luncheon was served to all of the members and guests. This meeting was exceptionally well attended and proved to be a decided success.

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held its first regular May monthly meeting on Monday evening, May 14 at 8:00 p.m. in east wing of the 15th floor of the General Motors building, Detroit.

The subject for discussion for this meeting was a paper entitled "Refractories for Heat Treating Furnaces," presented by C. C. Hayward, Service Manager of the Walsh Fire Clay Products Company of St. Louis, Mo. Mr. Hayward illustrated his paper with stereopticon slides and brought out many points of information and interest to the steel treaters, especially the one who is concerned with the design and construction of heat treating equipment. The subject of suitable refractories has been one which has been deserving of considerable investigation and study although apparently the surface has only been scratched. Mr. Hayward's paper brought out many interesting points in which he presented many of the difficulties which confront the manufacture of refractories.

The refractories situation is one of the limiting factors in the metallurgy of iron and steel as well as the metallurgy of some of the nonferrous metals which is today limiting the development of metallurgy. This subject has been given considerable investigation and research but there is still room for a whole lot more.

Following Mr. Hayward's paper a very lively and interesting discussion ensued which brought out many additional points of interest and information to the members who had the privilege of attending this meeting.

The usual get-together dinner was served at 6:30 p.m. in the meeting room and was attended by a large number of members and guests.

The Detroit chapter of the American Society for Steel Treating held

its last meeting of the season on May 29 at the Tuller hotel at 8:00 p. m. The meeting was preceded by dinner at the Hotel Roof Garden at 6:30.

The speaker of the evening was J. V. Emmons, Cleveland Twist Drill Company, who presented an illustrated paper entitled "The Effect of Heat Treatment on the Machinability of Tool Steels."

At this meeting the election of new officers was held and the results will be published in the next issue of TRANSACTIONS.

An interesting entertainment was provided and an enjoyable time was spent by all.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held its May meeting on Friday evening, the eighteenth of the month at 8:00 p. m. at the Blatz hotel, East Water and Oneida streets.

W. R. Shimer, Bethlehem Steel Company, Bethlehem, Pa., presented a very capable paper entitled "The Manufacture of Steel." This subject was discussed in detail from the iron ore to the finished product, being illustrated with lantern slides, and thus it proved very instructive to all in attendance.

The usual dinner was served at 6:45 p. m. at the Blatz hotel.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday evening, May 4, at 8 p. m. in the auditorium of the Chase Metal Works, 236 Grand street, Waterbury, Conn.

The topic of the evening was entitled "Some Interesting Phases of Steel Inspection." The speakers were Frank P. Gilligan, Henry Souther Engineering Co., Hartford, Conn., and past president of the society; and T. H. Keshian, metallurgist Waterbury Mfg. Co., Waterbury, Conn. Both of these gentlemen are authorities on the process of acid etching and the paper proved very interesting and instructive to the large number in attendance.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held held its May meeting on Wednesday, the 16th, in the assembly room of the Merchants association of New York, 9th floor of the Woolworth building.

The paper of the evening was presented by Chas. M. Knight, Jr., of the International Nickel Co., and was entitled "Inspection of Steel." Mr. Knight's paper, which was illustrated with lantern slides, was presented in a very capable manner, discussing the subject in detail. He brought out many points which are of interest to every steel treater. A very lively discussion followed the presentation of the paper.

The usual dinner was served at 6:30 p. m. in the Post Keller restaurant.

NORTH WEST CHAPTER

The annual meeting of the North West chapter was held on Thursday evening, May 17 in the rooms of the Manufacturers' Club of Minneapolis.

200 Builders Exchange. The speaker for this meeting was W. R. Shimer, metallurgist for the Bethlehem Steel Company, Bethlehem, Pa., who presented a very interesting paper entitled "The Manufacture of Steel." Mr. Shimer illustrated his paper with stereopticon slides and traced in detail the manufacture of both carbon and alloy steels from the time it is taken from the ore beds until it is in its final form for use in the many industries.

The North West Chapter were especially fortunate in being able to obtain Mr. Shimer for this occasion who is an authority on the subject of both carbon and alloy steels. Mr. Shimer has had many years experience both in the manufacture of steel and the observation of the many uses to which it is put in the various industries. In addition to outlining the various methods of manufacture of steel he pointed out many of the failures which steel undergoes due to improper design of the components, improper heat treatment; or possibly due to defective steel, containing non-metallic inclusions.

Following Mr. Shimer's paper a lively and interesting discussion ensued which was participated in by many of the members of the North West chapter.

After the presentation of the paper of the evening the report of the nomination committee was read and the election of officers was held. Thos elected to office are as follows: Chairman, H. Kenneth Briggs, Minneapolis Electric Steel Castings Co.; Secretary-Treasurer, Alexis Caswell, Manufacturers' Club. Executive committee: H. A. Anderson, Mahr Mfg. Co.; Thomas L. Joseph, Bureau of Mines, University of Minneapolis; Frank G. Lilygreen, American Hoist & Derrick Co.; Sidney J. Pfaff, Pfaff & Bathke; Wm. I. Sweet, Auto Engine Works.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held its regular monthly meeting on April 27, at 8 p. m. in the Engineers' club, 1317 Spruce street.

The program for the evening included a very interesting paper by Dr. Haakon Styri, director of research, S. K. F. Industries, entitled "Melting and Refining of High Grade Steel with Special Reference to the Elimination of Impurities." Dr. Styri described in detail the methods employed in producing clean steel.

The second paper of the evening was presented by John J. Crowe, physical metallurgist, Hull division, Philadelphia navy yard, and was entitled "Pyrometry." Mr. Crowe, who is well known to Philadelphia heat treaters, has made an extensive study of pryometry and consequently gave a very capable presentation.

The usual dinner was served at 6:30 p. m. in the club dining room and was attended by a large number of members and guests.

The May meeting of the chapter was held on the 25th of the month at the Engineers' club.

The program for this evening consisted of a paper by Chas. E. Carpenter, president, E. F. Houghton & Co., entitled "What the Society Means to the Sustaining Member," and W. H. Eisenman, national secretary, spoke

to the members on "What the Society Means to the Executive." There were also short contributions by prominent executives.

A film of motion pictures prepared by the Bureau of Mines at the Cadillac Motor Co.'s plant and entitled "Story of the V Type, 8-Cylinder Motor Car," was an added feature, which proved very interesting.

The election of officers took place at this meeting and the results will be published in the next issue of TRANSACTIONS.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held its regular meeting in the Hawaiian room of the Wm. Penn hotel on Tuesday evening, May 1, at 8 p. m. The subject for discussion at this meeting was entitled "Shop Kinks" which was presented and handled by some of the practical shop men, members of the Pittsburgh chapter, who have wide experience in the heat treatment of steel. This meeting was in the nature of a round-table discussion and was conducted by representatives from some of the representative manufacturing companies in and around Pittsburgh, including the Westinghouse Electric & Mfg. Co., the Union Electric Steel Co., the R. D. Nuttal Co., Mesta Machine Co., Crucible Steel Co. and several others.

The points brought out by several of the speakers proved to be highly interesting to those who had the privilege of attending this meeting and many points of practical interest and value were presented.

At this meeting the following officers for the ensuing year were elected: *Chairman*—W. J. Merten, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. *Vice-Chairman*—DuRay Smith, 263 Highland avenue, New Kensington, Pa. *Secretary-Treasurer*—H. L. Walker, Crucible Steel Co. of America, Pittsburgh, Pa. The following *directors* were elected: N. B. Hoffman, Colonial Steel Co., Pittsburgh, Pa.; Prof. S. L. Goodale, University of Pittsburgh, Pittsburgh, Pa.; W. H. Reiger, Union Electric Steel Co., Carnegie, Pa.; L. D. Bowman, Vanadium Alloys Steel Co., Latrobe, Pa.; C. M. Johnson, Crucible Steel Co. of America, Pittsburgh, Pa.; G. L. Kronfeld, Vulcan Crucible Steel Co., Pittsburgh, Pa.; B. F. Weston, Union Drawn Steel Co., Beaver Falls, Pa.; W. B. Crowe, Carnegie Steel Co., Munhall, Pa.; W. J. McInerney, Pittsburgh Crucible Steel Co., Midland, Pa.; B. D. Saklatwalla, American Vanadium Co., Bridgeville, Pa.; R. H. Davis, Firth-Sterling Steel Co., McKeesport, Pa.; W. W. DeGarmo, Union Switch & Signal Co., Swissvale, Pa.; J. M. Camp, Carnegie building, Pittsburgh, Pa.; L. L. Uhler, Union Steel Casting Co., Pittsburgh, Pa.; R. C. Heaslett, Wheeling Mold & Foundry Co., Wheeling, W. Va.

The members of the Meetings and Papers Committee who were elected are as follows: C M. Johnson, *Chairman;* W. B. Crowe, J. M. Lessells, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; C. I. Niedringhaus, Mesta Machine Co., Pittsburgh, Pa.; J. A. Succop, Heppenstall, Forge & Knife Co., Pittsburgh, Pa.; H. C. Ihsen, Jones & Laughlin Steel Co., Pittsburgh, Pa.

The Membership Committee members are as follows: N. B. Hoffman, *Chairman;* O. B. McMillen, Pittsburgh Rolls Corp., Pittsburgh, Pa.; D. H. Horne, Mesta Machine Co., Pittsburgh, Pa.; G. L. Kronfeld, W. H. Reiger, M. W. Caruthers, 439 Franklin avenue, Wilkinsburg, Pa.; H. L. Walker.

The personnel of the Publicity Committee is as follows: A. N. Armi-

tage, *Chairman,* Mesta Machine Co., Pittsburgh, Pa.; H. Neeb, Standard Chemical Co., Pittsburgh, Pa.; A. M. Cox, Pittsburgh Commercial Heat Treating Co., Pittsburgh, Pa.; H. L. Walker, DuRay Smith.

The following members were elected to serve on the Reception Committee: G. L. Kronfeld, *Chairman;* M. W. Caruthers, W. J. McInerney, and J. K. Miller, 558 Johnston street, Wilkinsburg, Pa.

The following Finance Committee was elected: S L. Goodale, *Chairman;* J. K. Miller, Frank Garratt, Latrobe Electric Steel Co., Latrobe, Pa.; T. D. Lynch, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; J. Trautman, Jr., Colonial Steel Co., Pittsburgh, Pa.

Those elected to serve on the Entertainment Committee are as follows: D. H. Horne, *Chairman;* W. H. Phillips, R. D. Nuttall Co., Pittsburgh, Pa.; N. B. Hoffman and DuRay Smith.

With this large body of members serving on the committees of the chapter, there is no doubt but that it will have a very successful year.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its regular monthly meeting Friday evening, May 18 at 8:00 p.m. at the Nelson Hotel. The speaker for this meeting was H. B. Knowlton of the Milwaukee Vocational School of Milwaukee, Wisconsin who presented a very interesting paper entitled "Carburizing" which was well illustrated with stereopticon slides. As the subject of carburizing had not been discussed before the Rockford Chapter prior to this meeting a very appreciative audience was on hand. Mr. Knowlton brought out many points of vital interest to the steel treater who is engaged in the carburizing of materials, pointing out many of the pitfalls which are apt to be present and which will in many cases result in inferior and perhaps rejected material. Following Mr. Knowlton's paper a very lively and interesting discussion ensued.

After the regular paper and business of the meeting had been taken care of the election of new officers for the coming year was held. This election will be announced in the next issue of TRANSACTIONS.

The usual get-together dinner was served at 7:00 p.m. at the Nelson Hotel and was attended by a good sized number of members and guests.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, April 27, at 8 p. m. in the Chamber of Commerce rooms, 47 Worthington street.

The paper of the evening was presented by William R. Bennett of the Bennett Metal Treating Co., Elmwood, Conn., and was entitled "Practical Steel Treating." Mr. Bennett spoke with authority on the subject having had many years' experience along this line. His paper dealt with tools, carburizing and heat treatment in general.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held its regular monthly meeting on April 26 at the Yates hotel. There were

two sets of motion pictures presented at this meeting, one set was entitled "The Story of the Automobile," and the other "The Story of Alloy Steels." These films proved very interesting to the large number of members and guests in attendance.

The usual dinner was served at the Yates hotol preceding the meeting.

TRI CITY CHAPTER

The Tri City chapter of the American Society for Steel Treating held its regular monthly meeting on Tuesday evening, May 15, at 8 p. m. in the Davenport Chamber of Commerce rooms, Davenport.

George C. Richardson, Bethlehem Steel Co., Bethlehem, Pa., presented a very interesting and capable paper entitled "Manufacture of Steel." This subject was developed in a very interesting manner, with motion pictures tracing the manufacture of steel from the iron ore to the finished product including many of the special alloy steels as well as the carbon steels. In addition to describing in detail the methods used in the manufacture of steel, Mr. Richardson outlined and described many of the failures of finished components due to inherent defects or to improper heat treatment or to the selection of the wrong kind of material for a given component, placing great stress on the importance of the necessity for having clean steel to start with and then properly heat treating this material.

Motion pictures were also presented showing the manufacture of wire and nails as well as the manufacture of steel car wheels.

Following Mr. Richardson's paper a very lively round table discussion, lead by R. B. Kerr, was held on the heat treatment of three typical tools upon which the standards committee of the national society had asked each chapter's opinion.

The usual get-together dinner was served at 7 p. m. in the rooms of the Davenport Chamber of Commerce and was attended by a large number of members and guests.

At this meeting the following officers for the ensuing year were elected: *Chairman,* H. Bornstein, Deere & Co., Moline, Ill.; *vice-chairman,* L. S. Rasmussen, Linograph Co., Davenport, Ia.; *secretary-treasurer,* C. A. Schoessel, John Deere Harvester Works, East Moline, Ill.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held its regular monthly meeting on May 25 at 8:00 p. m. in the auditorium of the New Interior Department buildng.

The paper of the evening was presented by Dr. P. D. Merica, director of research, International Nickel Company, New York City, and was entitled, "Metallurgy and Uses of Nickel." Dr. Merica gave a very capable presentation discussing the extensive applications of nickel in both ferrous and nonferrous metallurgy. He also covered the methods of smelting and refining.

There was a large attendance at this meeting and an enjoyable evening was spent by all.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held a meeting on Friday evening, May 4 at 8:15 p.m. in the Metal Trades Rooms, 44 Front Street, Worcester, Mass. The speaker for this meeting was Victor O. Homerberg of the Massachusetts Institute of Technology who presented a very interesting and instructive paper entitled "The Microscope as an Aid in the Solution of Practical Steel Problems." Mr. Homerberg presented his paper in a practical way and kept away from the highly technical side as much as was possible. He pointed out the many uses of the microscope in determining difficulties which arise in steel due to the many stages of manufacture which it goes through. He pointed out, that in many cases the microscope is the only means of determining certain defects in steel. This paper proved to be highly interesting and was well illustrated with stereopticon slides. Following the presentation of his paper Mr. Homerberg answered many questions and points of discussion. This meeting proved to be highly successful as evidenced by the large number of members and guests who were present.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ATKINSON, RHA L., (M-5), U. S. Geological Survey Dept., Interior Bldg, Washington, D. C.
BAILEY, F. J., (M-5), 520 Marquette St., Syracuse, N. Y.
BAUMGARN, ALBERT E., (M-5), 1316 26th St., Rock Island, Ill.
BENSON, A. W., (A-5), 2533 Broadway Cleveland Ohio.
BROWN-LIPE-CHAPIN CO., (S-5), Syracuse, N. Y.
CARHART, RAYMOND, O., (M-5), 623 Oneida St., Syracuse, N. Y.
CONNOLLY, JAS. H., (M-5), Standard Machinery Co., Auburn, R. I.
COOK, J. W., (A-4), 769 S. Central Ave., Los Angeles, Cal.
COYLE, ARTHUR J., (M-5), 934 N. Notre Dame Ave., South Bend, Ind.
CUSTER, GRANVILLE Y., (M-3), 133 N. 4th St., Reading, Pa.
DICKSON, J. C., (M-5), Inland Steel Co., Indiana Harbor, Ind.
DOUGHTY, H. E., (A-4), Atlas Steel Corp., 1420 Penna. Bldg., Philadelphia, Pa.
EAKIN, WM. C., (A-5), 707 Berkshire Ave., Pittsburgh, Pa.
ENGLAND, EARL E., (M-5), 3813 Washington Blvd., St. Louis, Mo.
FLANNERY, MICHAEL, (M-4), Royal Typewriter Co., 150 New Park Ave., Hartford, Conn.
FORSYTH, ARTHUR E, (Jr-5), 1206 5th St., Minneapolis, Minn.
FREYERMUTH, GEO., (M-5), 303 S. Michigan St., South Bend, Ind.
GEARING, CHAS. M., (M-5), New Departure Mfg. Co., Hartford, Conn.
GILLIGAN, JOHN WM., (M-5), P. O. Box 154, Windsor, Conn.
GREGG, JAMES L., (Jr-5), Box 80, Rolla, Mo.
GRUNDLER, HAROLD A., (Jr-2), 1275 E. 115th St., Cleveland, O.
HAJDUCK, S., (M-4), 2705 S. 63rd St., Berwyn, Ill.
HALL, FRANK A., (M-5), M. J. Ryan Co., Wesley Bldg., Philadelphia, Pa.
HAYS, LOUIS B., (A-5), Box 264, Pittsburgh, Pa.
HEATH, JAS. A., (M-5), 291 Devon St., Kearney, N. J.
HENNINGER, A. W., (S-5), New Process Gear Co., Inc., 500 Plum St, Syracuse, N. Y.
E. F. HOUGHTON & CO., (S-5), 612 Putnam Bldg., Davenport, Iowa.
JOHNSON, ADRIAN J., (Jr-5), 2501 5th Ave., Rock Island, Ill.
JOHNSON, OLIVER E., (M-4), 125 St. Paul's Pl., South Bend, Ind.
KNOBLOCK, EUGENE, (Jr-5), 1040 Portage Ave., South Bend, Ind.
KOSTER, J. L., (M-3), Royal Typewriter Co., 150 New Park Ave., Hartford, Conn.
KRON, C. L., (Jr-5), 1812 23rd Ave., Moline, Ill.
MEIER, F. F., (M-5), 5304 N. Front St., Philadelphia, Pa.
PAFFENBERGER, JOHN, (M-4), 1018 Michigan Ave., St. Joseph, Mich.
PARISH, H. C., (M-4), Arthur D. Little, Inc., Cambridge, Mass.
PASCOE, C. F., (M-5), Canadian Steel Foundries, Ltd., Long Point Plant, Montreal, Can.
POTTER, W. WALLACE, (M-5), Potter & Johnson Machinery Co., Pawtucket, R. I.
REUTER, A. E., (M-5), 1419 S. 51st St., Philadelphia, Pa.
ROBERTS, J. P., (M-5), 3039 W. Grand Blvd., Detroit, Mich.
ROHLOFF, JOS. H., (M-5) 6146 Dorchester, St., Chicago, Ill.
RUTTER, CLEMENT C., (M-5), 812 S. Schuylkill Ave., Philadelphia, Pa.
SINDT, ERNEST F., (Jr-5), 1918 Sturtevant St., Davenport, Iowa.
SKOOG, CARL F., (M-5), 2510 Erskine Blvd., South Bend, Ind.
STREET, GEO. L., (M-5), P. O. Box 515, Richmond, Va.
WHITAKER, WHARTON, (M-5), P. O. Box 795, Wm. H. Haskell Mfg. Co, Pawtucket, R. I.
WILLIAMS, J. J., (M-5), 23 Orient St., Meriden, Conn.

WILSON, JAS. M., (M-4), 648 N. 15th St., Philadelphia, Pa.
WUPPER, WALTER P., (Jr-5), 1725 Sturtevant St., Davenport, Iowa.
WYNN, PAUL C, (M-4), P. O. Box 475, Buchanan, Mich.

CHANGES OF ADDRESS

BEELER, CHAS., from 12005 Fairport Ave., to 3188 W. 17th St, Cleveland, O.
BERRY, RUSSELL M., from 1925 N. 11th St., Philadelphia, to 6602 Higerman St., Tacony, Philadelphia, Pa.
BOWERS, WHEELER, from 529 E. 123rd St, to 464 E. 129th St., Cleveland, O.
DESMOND, JOHN J., from North East Electric Co., to 522 Lake St., Rochester, N. Y.
DUMAS, M. G., from 1708 135th St., E. Chicago, Ill., to 17 Townsend St., Pittsburgh, Pa.
FAULK, WM. M., from Yellow Sleeve Valve Engr. Co., E. Moline, Ill., to 1469 Wanamaker St. W. Philadelphia, Pa.
GILMOUR, M. L, from 316 McKinney Ave., to Reynolds Wire Co., Houston, Tex.
HART, ALEX JR., from Amer. Iron Prod. Co., 107 Liberty St., to 44 Whitehall St., New York City.
HOBBS, D. B., from 407 Thorn St., Warren, O., to 2210 Harvard Ave., Cleveland, O.
HOLMES, J. Q. f,rom 1031 N. Pennsylvania Ave., Indianapolis, Ind., to Y. M. C. A., Anderson, Ind.
JEWETT, M. G., from Interstate Iron & Steel Co., E. Chicago, Ind., to 118th & Calumet River, Chicago, Ill.
KARLE, C. E., from 5 Tucker St., Milton, Mass., to 131 Homes St., Dorchester, Mass.
KUTAR, P., from 258 Oakland Ave, Pittsburgh, Pa., to 204 Robinson St., Pittsburgh, Pa.
LEBARRE, R. S., from Interstate Iron & Steel Co., Chicago, Ill., to LeBarre Steel Co., 504 Union Bldg., Cleveland, O.
LEDIN, THEO. E., from 71 Gladstone Ave., to 2902 Vicksburg, Detroit, Mich.
LONGLEY, G. S., from 162 Capitol Ave., to 92 Sharon St., Hartford, Conn.
McKINNEY, H. D., from Driver-Harris Co., 28 S. Jefferson St., to Driver-Harris Co., 564 W. Randolph St., Chicago, Ill.
MILLARD, F. G, from 15412 Center St., to Elk's Club, Harvey, Ill.
MILLER, R. W., from 409 Wilbraham Rd., Springfield, Mass., to 366 Park St., W. Springfield, Mass.
OTTE, CHAS. F., from 7139 Hermitage St., Pittsburgh, Pa., to 7312 Florence Ave., Swissvale, Pa.
PETERSON, J. W., from 448 Underwood St., to River Bank, Riverside Blvd. Rockford, Ill.
PIERCE, PAUL, from 3821 E. Wassington, Indianapolis, Ind., to Ferry Cap & Set Screw Co., Scranton Rd., Cleveland, O.
PRIESTLEY, J. W., from Pittsburgh Crucible Steel Co., Midland Works, Midland, Pa., to 105 S. Lexington Ave., Pittsburgh, Pa.
SCHAGRIN, H., from 1008 E. 42nd Pl, to 1408 E. 69th St., Chicago, Ill.
STENGER, BERNARD H., from Sheldon Axle & Spring Co., Wilkes Barre, Pa., to Queen City Steel Treating Co., Cincinnati, O.
WEBB, GORDON A., from 105 Manistique Ave., to 408 Manistique Ave, Detroit, Mich.
WHYTE, W. C., from Steel Improvement Co., 5003 Windsor Ave., Cleveland, O., to Electro Alloys Co., Elyria, O.

MAIL RETURNED

MUNGAN, J. J., 617 Ford Bldg., Detroit, Mich.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

WANTED—POSITION AS SUPERVISOR of a heat treating department. Have had 12 years experience in heat treating, tool and die hardening. Address 4-5

WANTED—POSITION AS HARDENER. Have had 5 years practical experience with a large firm in general hardening of both carbon and high-speed steel as well as carburizing. Fully competent. Age 35. Married. Address 4-10.

METALLURGIST WITH 8 YEARS EXPERIENCE in the analysis of ferrous and nonferrous metals, physical testing, metallography and heat treatment of plain and alloy steels, desires responsible position in laboratory of well established concern. Address 4-15.

POSITION IS DESIRED AS FOREMAN OF HEAT TREATING DEPARTMENT. Seven years of high grade experience with carbon, high speed, and alloy steels, covering all phases of heat treating. Best references. Address 4-20.

POSITION WANTED IN METALLURGICAL LABORATORY. Seven years of high grade experience in metallographic testing, research work and experimental heat treating; also pyrometry technical training. Best references. Address 4-25.

EXPERIENCED TOOL HARDENER would like a position in or around New York. Has had 11 years experience. Can harden and carburize all kinds of steel. Can give first class references if desired. Address 4-30.

AS WORKS SUPERINTENDENT with 16 years of high grade experience in all branches of tool and metal parts manufacturing. Can assure maximum quality production at a minimum cost. Best of references. Address 4-35.

ASSISTANT METALLURGIST. Ten years practical experience in heat treating department and laboratory of several well known concerns. Boston district preferred. Salary $150.00 per month. Married. Address 5-10.

METALLURGIST—1916 Graduate with six years experience as chief chemist and chief metallurgist. Thoroughly familiar with ferrous and non-ferrous analysis, metallurgy, metallography and physical treatment. Has had also good production experience, havin had charge at Steel melting and heat-treating departments. During past year has been metallurgist for a Government Arsenal, in charge of ferrous and non-ferrous research and testing. Available at once. Address 6-1.

POSITION WANTED

FOUNDRY CHEMIST AND METALLURGIST, capable of supervising the manufacture of steel, malleable and gray iron castings. Expert on converter steel practice, heat treatments and facing sands. Has had 15 years experience. Address 6-5.

CHEMIST AND HEAT TREATER desires a position in laboratory or heat treating department, experienced in chemical and physical testing of iron and steel and other alloys. Eastern location preferred. Reasonable salary. Address 6-10.

POSITIONS OPEN

SALES ENGINEERS WANTED young single men for positions as sales and service engineers, calling on superintendents, managers, engineers, chemists and metallurgists, for manufacturers of well known high-grade automatic electrical and temperature equipment, extensively used in factories, power plants, chemical and industrial works. Knowledge of physics and elementary electricity required. Graduates of technical schools preferred. Candidates must be free to travel in the great manufacturing and industrial districts. Young men of good address and ability to talk convincingly to engineers wanted, but no previous experience demanded. Write describing education and earning experience, if any, and stating age and salary desired. Address 6-15.

POSITION OPEN IN GEAR PLANT located in Berkeley, California for practical heat treatment foreman who is familiar with carburizing and general heat treatment details. Expert metallurgist not a requirement but a man possessing thorough knowledge of the heat treating game. Address Johnson Gear Company, 232 Rialto Building, San Francisco, California giving full information and salary required.

DIE BLOCK DESIGNER and hardener wanted by an eastern concern who manufacture die blocks. This position offers an excellent opportunity for one who has had experience in both the designing and hardening of blocks. State experience and qualifications. Address 4-40.

TOOL STEEL SALESMAN. New England States. Prefer one acquainted with the trade and now handling similar line. Do not apply unless you have had experience. This is one of the largest tool steel companies in the country, and affords a splendid opportunity for the right man. Address 3-5.

WANTED A THOROUGHLY COMPETENT, energetic man, preferably techical, to sell pyrometers regulators, etc., in Michigan District. Only high grade men who can produce results need apply. Give present employment, age, married or single, training, references, and income expected. Address 5-5.

Items of Interest

D. W. McDOWELL, formerly chief inspector for the Jones and Laughlin Steel Company and for 4 years secretary-treasurer of the Pittsburgh chapter of the American Society for Steel Treating, has been appointed manager of the Pittsburgh district of the American Life Insurance Company, with offices at 309 East End Savings and Trust Building, Pittsburgh.

For a number of years Mr. McDowell has been studying the insurance business and as a result has severed his intimate connections with the steel business. As an organizer and expert steel man Mr. McDowell has proven his ability and capacity during his association with Jones and Laughlin and as secretary-treasurer of the Pittsburgh chapter of the American Society for Steel Treating. Mac has done some great work. His interest and effort has been largely responsible for the steady growth of the Pittsburgh chapter and we regret that he is now leaving our fold.

In his new work we are confident that he will make a very reputable showing and we wish to assure him that he has our best wishes for a very successful career in his new enterprise.

The New England Heat Treating Service Co., of Hartford, Conn., has recently been incorporated with $10,000.00 capital to act as sales representatives for a number of leading manufacturing firms manufacturing heat-treating appliances.

The officers of the firm are Stanley Rockwell, consulting metallurgist of Hartford, as president and treasurer; Warren D. Fuller, formerly of the New Departure Mfg. Co., as vice president; Isaac D. Russell, secretary of the American Hardware association, is a member of the board of directors, together with H. W. Staples, works manager of the Bristol Brass Co.

The company began business operations on March 25 and report a very successful business in the territory covering Connecticut, Western Massachusetts, Maine, Vermont, New Hampshire and four counties in the northern part of New York.

The New England Heat Treating Service Co., Inc., is special representative in the territory mentioned above for the Wilson-Maeulen Co., manufacturers of pyrometers and of the "Rockwell Direct Reading Hardness Tester"; for the American Gas Furnace Co.; for the Rodman Chemical Co.; and for the Cutler Steel Co. The company is marketing several commodities manufactured by themselves.

Advances in the Metallurgy of Iron and Steel and Their Influence Upon Modern Engineering, is the title of an address by Sir Robert A. Hadfield, Bt., which was delivered before the Cambridge University Engineering society, on Thursday, Jan. 25, 1923, and is now in pamphlet form. There are two parts to this, part one relating chiefly to Cambridge and engineering, and part two relating to metallurgy and metallurgical chemistry and their application to modern engineering. The lecture was illustrated with cinematograph and lantern slides as well as exhibits.

W. J. Priestley has resigned as works manager, Pittsburgh Crucible Steel Co., Midland, Pa., to become associated in a metallurgical capacity with the Electro-Metallurgical Sales Corp. with headquarters in Pittsburgh. Mr. Priestley, before going with the Pittsburgh Crucible Steel Co., was steel superintendent at the Naval Ordnance plant, Charleston, W. Va., and prior to that was with the Bethlehem Steel Co., at South Bethlehem. He was graduated from Lehigh with the class of 1908. His successor at Midland is R. M. Keeney, who has been general superintendent, Central Iron & Steel Co., Harrisburgh, Pa.

Ray P. Johnson has been elected president of the Warner Gear Co., Muncie, Ind. He will fill this office in addition to his present position of general manager.

William R. Gorham has been appointed advising engineer for the Tobatta Foundry Co., Tobatta, Kyusha, Japan. He was previously chief engineer and factory manager for the Jitsuyo Jidosha Seizo Kabushi Kaisha, Nishi-ku, Osaka, Japan.

Reginald Clark, superintendent J. H. Williams & Co., has joined the Western Drop Forge Co., Marion, Ind., in an important executive capacity. Prior to 1918, when he became associated with the Williams company, Mr. Clark was for several years an executive of the Rolls-Royce Co. in Derby, England, and during the war was detailed by the company to supervise the production in the United States of forgings used in the Rolls-Royce battle plane motors. He sailed on March 24 for England, where he will investigate forge practices in the interests of the Western Drop Forge company. Upon his return he will take up his work at Marion.

The Cleveland office and warehouse of the William Jessop & Sons, Inc., 91 John St., New York City is now located at 1277 W. 9th St., Cleveland, Ohio. This office is under the able direction of V. M. Wellman who has been actively engaged in selling steels for many years.

The Annual Meeting of the Iron and Steel Institute held on Thursday and Friday, May 10 and 11, at the House of the Institution of Civil Engineers, Great George Street, London, S. W. 1., proved to be a very decided success. Many valuable and interesting papers were read. The annual dinner was held on the evening of Thursday, at the Connaught Rooms, Great Queen Street, London, W. C., and was attended by a large number of the members of the Institute.

Rowland S. LeBarre has incorporated the LeBarre Steel Co., with headquarters at Cleveland, 504 Union building, 1836 Euclid avenue, for the purpose of acting as distributor in Indiana, Michigan, Ohio, Illinois and Wisconsin of the Sizer Steel Corp.'s "Elektrik Furnace Steels," consisting of "Sizer's Well Known Die Blocks," also tungsten, bearing, tool, high-speed, alloy and carbon bars and billets.

Mr. LeBarre started in the order department of the Illinois Steel Co., Chicago, in the nineties. In 1902 he was sent to New Orleans, when a joint office was opened by Illinois, Carnegie and American Sheet Steel companies. In 1905 he was transferred to the Cleveland office as assistant manager of sales, where he remained until July, 1919, when he joined the Interstate Iron & Steel Co. at Chicago, in charge of their alloy sales, where he remained until his resignation, March 1, 1923.

F. J. Griffiths who has been elected president of the Central Steel Co., following the organization of the company in 1914, was vice president and general superintendent. He is a graduate of the Case School of Applied Science. He first became connected with the steel industry when he became identified with the United Steel Co., Canton, O., shortly after graduating from college. He remained with this company until the formation of the Central Steel Co. Other changes in the Central organization include the election of R. E. Bebb former president, as chairman of the board of directors; C. E. Stuart, vice president and treasurer; J. M. Schlendorf as vice president in charge of sales; B. F. Fairless, as vice president in charge of operations; and C. C. Chase Jr., as secretary. Mr. Schlendorf and Mr. Fairless also were added to the board of directors of the company.

John P. Brown, for the past three years engaged in rehabilitation work with the Philadelphia Power Plant Engineering school in the capacity of instructor of machine shop practice and tool making, terminated his connection with that organization on May 31, 1923, and has taken up his duties as general manager of the Ace Hardware Mfg. Corp., Philadelphia, Pa.

Dr. Ira N. Hollis, a past president of the American Society of Mechanical Engineers, has tendered his resignation of the presidency of Worcester Polytechnic Institute, Worcester, Mass., to take effect at the convenience of the board of trustees. His letter says that he will be glad to remain until a fitting successor is chosen, but he has set three years as the limit of his further service. At the end of that time he will be 70 years old. He will devote the next few years to literary work which he has been planning for a long time. President Hollis went to Worcester 10 years ago from Harvard University, where he had been professor of engineering from 1893, in which year he resigned from the United States Navy. He was graduated from the Naval Academy in 1878. At Harvard he was chairman of the athletic committee, and under his direction the Harvard Union and the stadium were designed and built.

The Vanadium Alloys Steel Co. announce the occupancy of their new Chicago office and warehouse, located at 1440 West Lake street. W. R. Mau is the district manager.

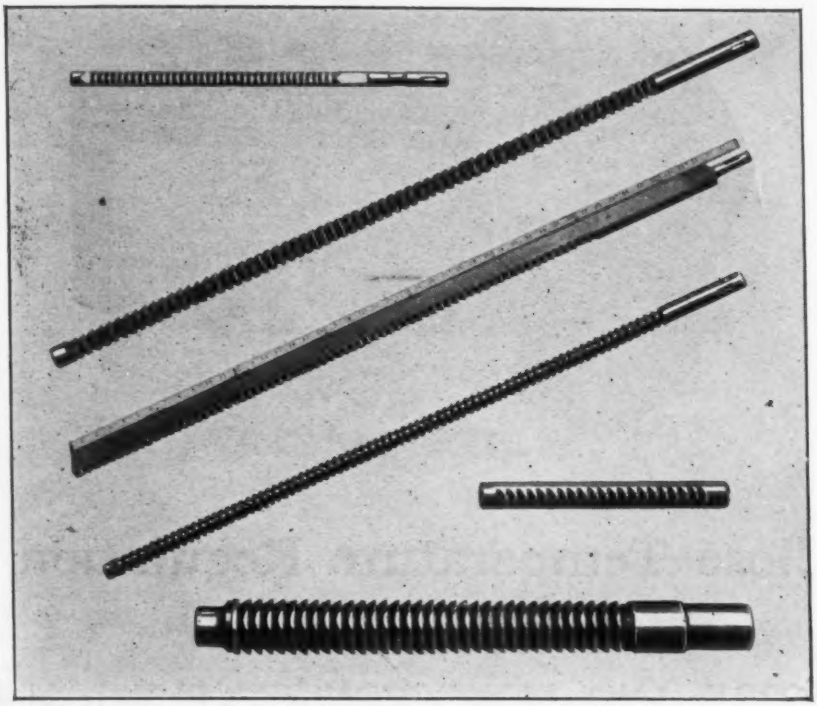
This building has been designed and built especially to meet the requirements of their rapidly growing clientele in the Chicago district. Stocks of "Vasco" tool steels have been greatly augmented and facilities for handling and shipping so extended that prompt attention and delivery are absolutely assured.

Associated with Mr. Mau, as special representatives, are Messrs. A. G. Henry, R. F. Noonan and C. R. Trimmer; the latter in direct charge of the Wisconsin and Minnesota territory, with headquarters at 412 Loan and Trust building, Milwaukee.

The Central Steel Co. of Massillon, O., manufacturers of alloy steel products for the automotive industry has decided to enlarge its field activities, by the addition of special alloy steels for railroad service, such as axles, springs and reciprocating parts of locomotives. This department will be under the direction of Irving H. Jones, director of railroad development with office in the Peoples Gas building, Chicago. Mr. Jones was formerly sales engineer with Joseph T. Ryerson & Son.

The Pittsburgh branch of the Metal & Thermit Corp., on May 1 will be moved from 801-807 Hillsboro street, Corliss station, to 1514 Fayette street, Northside. In order to care for the increasing business in the territory a modern welding shop is being constructed at the new quarters.

BETHLEHEM



Broaches of the size and length shown above, (the largest being 50" long), must be made of a steel that will meet certain definite requirements.

Bethlehem Tool Room Oil Hardening Tool Steel was used because—

it is hard
it is tough
it hardens uniformly
it is non-shrinking
it is non-warping

—and it accomplished the job.

"Tool Steel Catalog" on Request

BETHLEHEM STEEL COMPANY

***General Offices:* BETHLEHEM, PA.**

Sales Offices:

New York, Boston, Philadelphia, Baltimore, Washington, Atlanta, Pittsburgh, Buffalo, Cleveland, Cincinnati, Detroit, Chicago, St. Louis, San Francisco

HEART TO HEART TALK WITH STEEL TREATERS

By the President of *E. F. HOUGHTON & CO.*

THE other day I happened to be in one of our Branch Offices, when one of our salesmen came in with a tale of woe, that a competitor had quoted a casehardening material warranted to be as good as Houghton's Pearlite Carburizer, for two dollars a ton less and our customer had claimed that it would do better work.

"Well, there you are!" Said the District Agent to whom the salesman was reporting, as he turned to me, believing that he had thoroughly convinced me that Houghton was not deuce high in an old deck when it came to selling Casehardening Materials.

"Two dollars a ton don't mean anything," said I, to the astonishment of both. Casehardening materials are purchased by the pound, but they are valued by the bushel. That is to say, the user of casehardening material is not so much interested with the cost per ton as he is with the cost per pot and the number of times the material may be reused.

So I personally called the customer on the 'phone and asked them if they would either let us have a sample of the competing material, or make a comparison in the weights themselves. They declined to give us a sample of our competitor's goods, which was all as it should have been, but they did make a comparison in weight and were surprised to discover that the Pearlite was costing less per pot.

I then made a personal call on the customer, in company with the salesman, and this is about what I said:—

"Our Company asks for no favors unless those favors are enjoyed. We have pioneered the casehardening material business and have been the very first to market every improved product. We have conducted the most extensive research endeavors and we have rendered a service to the steel treaters of the World, of whom we have the confidence of a very large majority. Now this $2.00 cut per ton made by a competitor, may or may not be economy. Whether it is or is not, we do not want to be in a stage of continual argument and doubt, so why not give our competitor an order for a car; use it carefully, make your own honest comparisons and then you will know something. If the competition is real, then it is up to Houghton to do what they have always done—find some way to beat it; if it is imaginary, let's forget it."

The buyer was reluctant to order the trial car lot, being willing to take our word for the superiority of Pearlite, but we insisted as a special favor that there should be a show-down and finally our wishes were granted and the trial car of competitor's material ordered.

While we believe that we have enjoyed 100% of the trade of this buyer since that time, we have never to this date been able to obtain the details of their test of the competitor's car.

Now you know as much as I do and you may draw your own conclusions.

But the difference in measure is not the only advantage which the lighter material possesses. You must remember that the lighter material possesses the greatest thermal conductivity and will, therefore, require less time to heat to the carburizing temperature than the heavier material, and in addition to this, the lighter material being more porous will permit of a freer circulation of the casehardening gases, a more uniform consumption or absorption of those gases, reduce the time of the operation and increase the number of times the material may be used without exhaustion.

From a sample of the same competing material which I afterwards obtained from another source, I estimated that the actual cost of the Pearlite was $7.00 per ton less than the competing material, even though the first cost of the competing material to the customer was $2.00 per ton less.

There are some few concerns fooling themselves into believing that they are purchasing the most economical material, because the first cost is a dollar or so less per ton than the first cost of Houghton's product.

I do not mean to say that the casehardening material which is the lightest in weight is necessarily the best and cheapest, as that is known not to be true, because bone and leather charcoal products will weigh more than wood charcoal products and the former, generally speaking, are superior in every way, for the particular work upon which they are universally used. But I do mean to say, that as between two casehardening materials, both made from wood charcoal, the one made from that wood charcoal weighing the least, will be the best and within a reasonable differential in price prove to be the most economical.

Now just a word about these Talks.

Every month I talk through these pages to every reader of the Transactions of the Society, and about as often as I talk through the medium of my own publication to not only the professional steel treaters, but those associated with concerns who do steel treating to the extent of some six-thousand.

Any fellow who talks too much makes errors.

The only chap who makes no errors is the one who says nothing and he usually knows nothing to say.

But give me credit for this.

What I do say is down in black and white where it may not be denied and I do not talk behind folks' backs and before you are influenced to believe that any of my statements are wrong, you ought to insist that the other fellow shall put his statements down in black and white also.

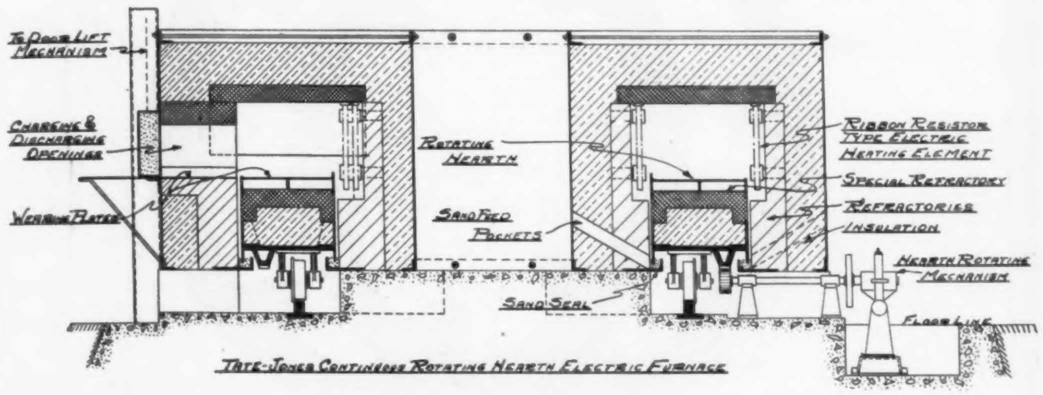
Yours fraternally,

CHAS. E. CARPENTER,

President of E. F. Houghton & Co.

Entered the service
of the Company as
Office Boy in 1880.

Heating Auto Parts for Quench and Draw Back in Continuous Rotating Hearth Electric Furnaces Gives Assured Uniformity



This furnace is being used for heating connecting rods for quenching—another furnace for the draw back. They were installed to eliminate irregular treatment and rejections. The results obtained fully recommend this equipment.

The plan below shows the working openings. A division wall protects the heated material from the cold charge insuring quench on a rising temperature. Speed of rotation gives any heating cycle.

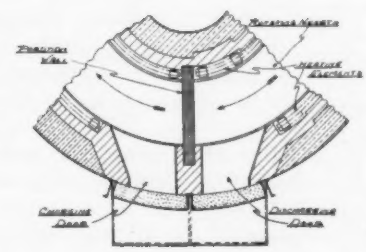
The economical features are:

1st. Uniform treatment (Quality).

2nd. Eliminating rejections (Saving Losses).

3rd. Greater production per floor space.

4th. Labor reduced.



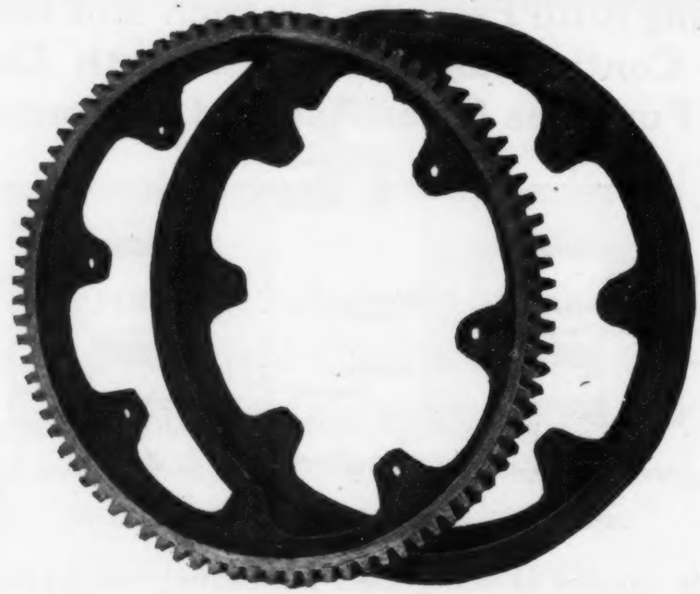
See Single Purpose references page 14 in June, July, August, page 13 November and February issues of TRANSACTIONS.

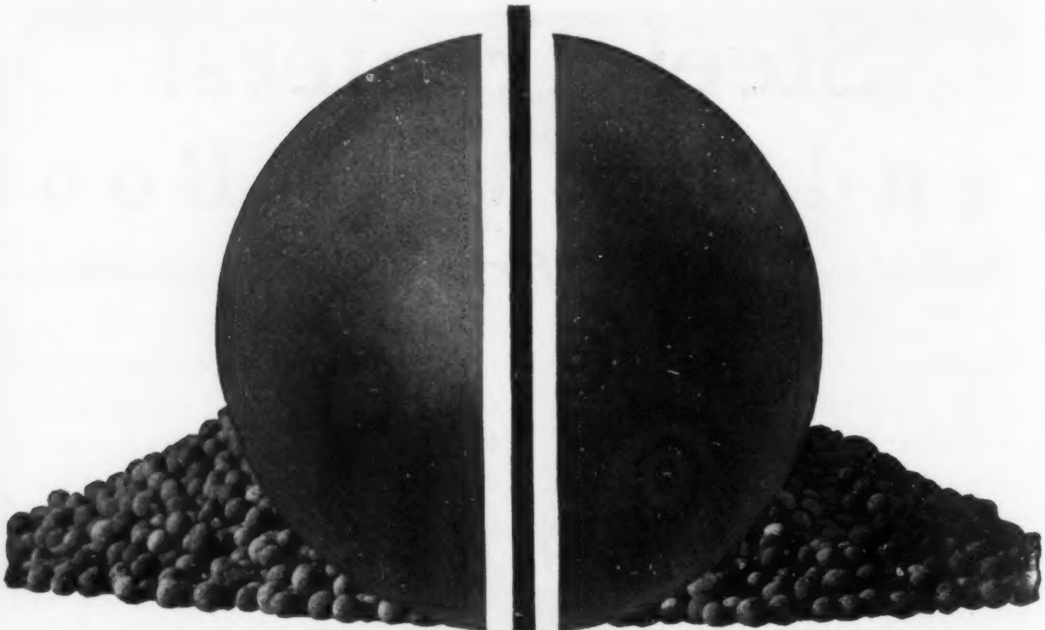
Tate-Jones & Co. inc.

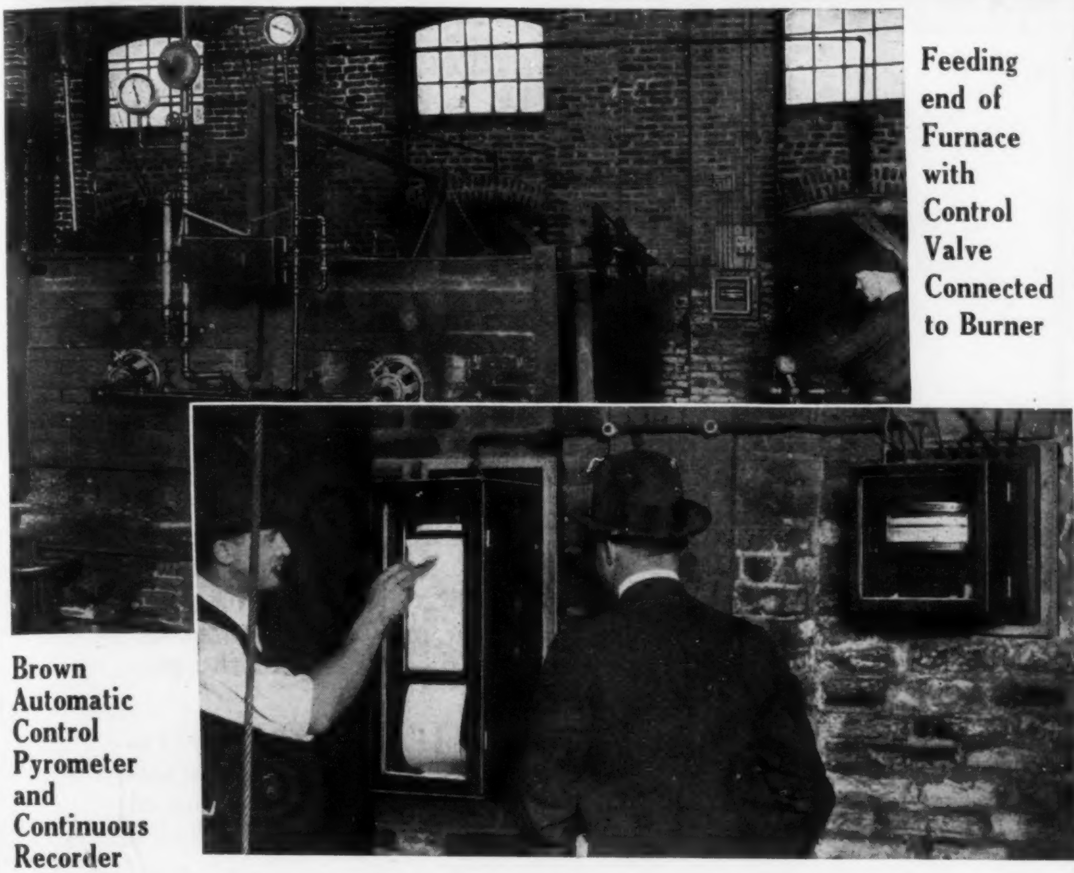
Furnace Engineers **Established 1898**

PITTSBURGH, PA.

New York — Detroit — Buffalo — Philadelphia — Chicago — San Francisco — St. Louis







Feeding end of Furnace with Control Valve Connected to Burner

Brown Automatic Control Pyrometer and Continuous Recorder

Brown Automatic Control Pyrometers

installed on Oil fired furnaces at Fayette R. Plumb Inc.

Like so many other pace-setters, Plumb's depend on Browns for correct temperatures. The Furnace shown is used for heat-treating axes and similar tools at a temperature of 1500° F. Fuel oil is used 30-32 gravity, at a pressure of 18 pounds. Both oil and air are entirely controlled by the Brown Automatic Valve which is in turn actuated by the Brown Automatic Control Pyrometer. A Brown Continuous Recording Pyrometer furnishes a permanent record of the heats carried.

Automatic control of oil, gas and electrically heated devices is both practical and easy with a Brown Automatic Control Pyrometer, and its advantages have been thoroughly demonstrated in actual service. Our Catalog No. 85 thoroughly covers the subject. Write for your copy today.

Address: The Brown Instrument Company, 4502 Wayne Ave., Philadelphia, or one of our district offices in New York, Boston, Pittsburgh, Cleveland, Columbus, Birmingham, Detroit, Chicago, St. Louis, Denver, Los Angeles, San Francisco, Montreal.

Brown Pyrometers

Most used in the world

FOUNDER MEMBERS
of the
AMERICAN SOCIETY FOR STEEL TREATING

THEODORE E. BARKER
Elmhurst, Ill.

WILLIAM P. WOODSIDE
Detroit, Mich.

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JOHN ALEXANDER MATHEWS, Sc. D .... New York City
ELWOOD HAYNES, B. S. .... Kokomo, Ind.
HENRY LE CHATELIER .... Paris, France

HENRY MARION HOWE MEDALIST

EMANUEL J. JANITZKY 1922

RULES GOVERNING THE AWARD OF THE HENRY MARION HOWE MEDAL

The Board of Directors of the American Society for Steel Treating has established a fund to be known as the Henry Marion Howe Medal Fund, the proceeds of which shall be used annually to award a gold medal to be known as the Henry Marion Howe Medal. The award will be made as follows:

(1) The medal will be awarded to the author of the paper which shall be judged to be of the highest merit. All papers in order to be considered must be published originally in the TRANSACTIONS of the Society during the twelve months ending August 1st of the year in which the medal is awarded.

(2) The competition for the Henry Marion Howe Medal shall be open to all.

(3) The award shall be made by the Board of Directors.

(4) The award may be withheld at the discretion of the Board of Directors.

SUSTAINING MEMBERS

The following firms and individuals, because of exceptional interest in the work of the Society have contributed not less than $25.00 each year for the promotion of its objects

National Society

COLUMBIA TOOL STEEL CO. .... Chicago Heights, Ill.
EDGAR ALLEN & CO., Limited .... Sheffield, England
GENERAL ALLOYS CO. .... Boston, Mass.
H. H. Harris, President
KELLY AXE MFG. CO. .... Charleston, W. Va.
W. C. Kelly, President
E. LEITZ, INC. .... New York City
A. Traeger, President
PELICAN WELL TOOL AND SUPPLY CO. .... Shreveport, La.
M. G. Stewart, Manager
SIMONDS SAW AND STEEL COMPANY .... Lockport, N. Y.
N. & G. TAYLOR COMPANY .... Philadelphia, Pa.
VANADIUM-ALLOYS STEEL COMPANY .... Latrobe, Pa.
W. S. Jones, Vice-President
VULCAN CRUCIBLE STEEL COMPANY .... Aliquippa, Pa.

Chicago Chapter

AM FORGE COMPANY .... Chicago, Ill.
F. A. Morrison, Manager of Sales
THE ATLAS STEEL CORPORATION .... Dunkirk, N. Y.
Harry Hardwicke
BARKLING FUEL ENGINEERING CO. .... Chicago, Ill.
Theodore Johnson, Engineer
COLUMBIA TOOL STEEL CO. .... Chicago, Ill.
E. H, Pasmore, Manager
DRIVER-HARRIS COMPANY .... Chicago, Ill.
H. D. McKinney, District Manager
INGALLS-SHEPHARD DIVISION OF WYMAN & GORDON CO. .... Harvey, Ill.

Chicago Chapter (Continued)

LUDLUM STEEL COMPANY....Chicago, Ill.
William A. Edwards, District Manager
PERFECTION TOOL HARDENING COMPANY....Chicago, Ill.
PULLMAN CAR WORKS....Chicago, Ill.
T. H. Branch, Asst. Superintendent
RICH TOOL CO....Chicago, Ill.
VAUGHN AND BUSHNELL MFG. COMPANY....Chicago, Ill.
H. A. Vaughn, Asst. General Manager

Cincinnati Chapter

AHRENS-FOX FIRE ENGINE COMPANY....Cincinnati, O.
ALLIS-CHALMERS MANUFACTURING COMPANY....Cincinnati, O.
AMERICAN ROLLING MILL COMPANY....Middletown, O.
ANDREWS STEEL COMPANY....Newport, Ky.
THE CINCINNATI BICKFORD TOOL CO....Cincinnati, Ohio
A. H. Tuechter, President
CINCINNATI MILLING MACHINE COMPANY....Cincinnati, O.
R. K. LE BLOND COMPANY....Cincinnati, Ohio
Harold Le Blond, Representative
LODGE & SHIPLEY MACHINE TOOL CO....Cincinnati, Ohio
J. Wallace Carrel, Vice-President
NILES TOOL WORKS COMPANY....Hamilton, O.
POLLAK STEEL COMPANY....Cincinnati, O.
TOOL STEEL GEAR & PINION COMPANY....Cincinnati, O.
U. S. PLAYING CARD COMPANY....Cincinnati, O.

Cleveland Chapter

THE W. S. BIDLE COMPANY....Cleveland, Ohio
CLEVELAND WIRE SPRING COMPANY....Cleveland, Ohio
Chas. H. Erickson
COLUMBIA TOOL STEEL CO....Chicago Heights, Ill.
G. C. Beebe, District Manager
MORRELL SALES AND ENGINEERING CO....Cleveland, Ohio
C. P. Morrell, President
WARNER & SWASEY CO....Cleveland, Ohio

Detroit Chapter

BELLEVUE INDUSTRIAL FURNACE CO....Detroit, Mich.
ALFRED O. BLAICH COMPANY....Detroit, Mich.
J. A. Howland
THE BRISTOL COMPANY....Waterbury, Conn.
H. W. Moss, District Manager
THE CENTRAL STEEL COMPANY....Massillon, Ohio
Arthur Schaeffer, District Sales Mgr.
CRUCIBLE STEEL CO. OF AMERICA....Detroit, Mich.
A. L. Ralston
DRIVER-HARRIS COMPANY....Detroit, Mich.
W. E. Blythe, District Manager
J. B. FORD COMPANY....Wyandotte, Mich.
C. S. Tompkins, Industrial Department
GENERAL ALLOYS COMPANY....Boston, Mass.
A. L. Grinnell, Detroit Manager
GEO. J. HAGAN & CO....Pittsburgh, Pa.
J. Sandberg, Detroit Representative
HOLCROFT COMPANY....Detroit, Mich.
H. L. Ritts, Sales Manager
E. F. HOUGHTON & CO....Philadelphia, Pa.
H. E. Cressman, District Manager
HUPP MOTOR CAR COMPANY....Detroit, Mich.
LEEDS & NORTHRUP....Philadelphia, Pa.
A. F. Moranty, Representative
LUDLUM STEEL COMPANY....Watervliet, N. Y.
J. E. Polhemus, District Manager
MELLING FORGE CO....Lansing, Mich.
J. W. Wilford, General Manager
MONTGOMERY CHEMICAL CO....Detroit, Mich.
L. C. Dunn, Manager
W. S. ROCKWELL CO....Detroit, Mich.
M. L. Hollister

Detroit Chapter (Continued)

RODMAN CHEMICAL COMPANY........Detroit, Mich.
G. A. Webb, District Manager

H. L. SHIPPY........Detroit, Mich.

STANDARD FUEL ENGINEERING CO........Detroit, Mich.
George H. Willett, President

SWEDISH CRUCIBLE STEEL CO........Detroit, Mich.

TATE-JONES & COMPANY........Dayton, O.
Edward Busch, Sales Manager

VANADIUM ALLOYS STEEL CO........Latrobe, Pa.
A. F. MacFarland, District Manager

WAYNE SOAP COMPANY........Detroit, Mich.
H. A. Montgomery, General Manager

Hartford Chapter

FRASSE STEEL WORKS........Hartford, Conn.
R. K. Newman, Secretary

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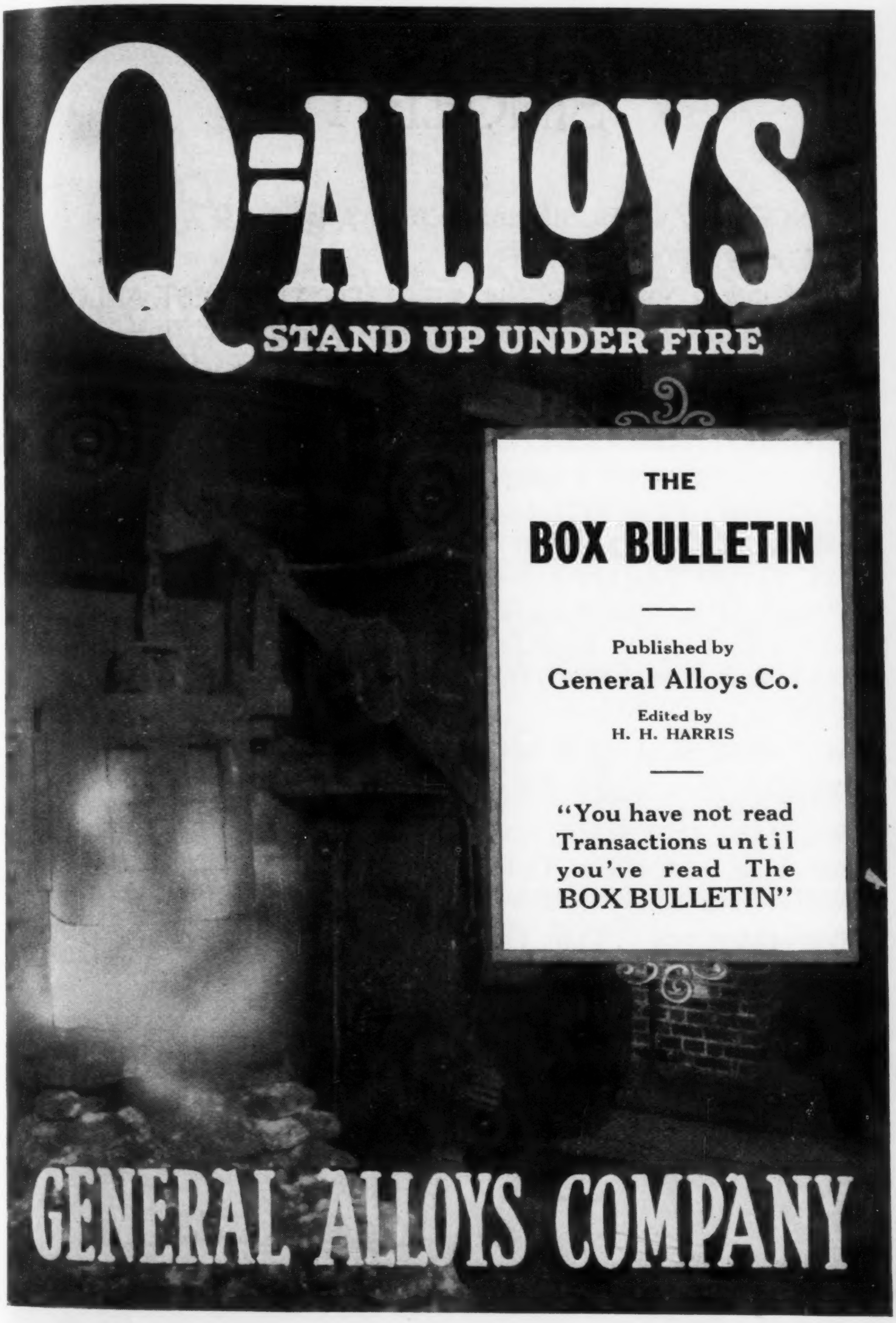
Q-ALLOYS
STAND UP UNDER FIRE
THE
BOX BULLETIN
Published by
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Edited by
H. H. HARRIS
"You have not read Transactions until you've read The BOX BULLETIN"
GENERAL ALLOYS COMPANY

BOX BULLETIN SUPPLEMENT

SINCERITY

SINCERITY IN BUSINESS IS AN ASSET.

WE HAVE FOUND IT SO.

FOR FOUR YEARS WE HAVE MADE THE BEST ALLOYS THAT OUR INTELLIGENCE AND OTHER LIMITATIONS PERMITTED.

WE HAVE WORKED HARD, OUR HEARTS IN OUR WORK, AND BOTH SHOULDERS TO THE WHEEL.

WE HAVE SPENT LARGE SUMS OF MONEY IN IMPROVING AND PERFECTING A PRODUCT WHICH HAS ALWAYS BEEN HEAD AND SHOULDERS ABOVE THE REST. WE HAVE TAKEN NO PROFIT FROM THIS BUSINESS, PAID NO INCOME TAXES, AND WORKED CONSISTENTLY CONTENT TO BUILD A PERMANENT BUSINESS RATHER THAN PROVIDE OUR WALLETS WITH A TEMPORARY LINING.

WE HAVE SOLD OUR MATERIALS ON MERIT ALONE.

WE GUARANTEED THEM ON CASH REBATE BASIS.

WE HAVE INFORMED OURSELVES IN THE USE AS WELL AS THE MANUFACTURE OF ALLOYS AND WORKED WITH THE HEAT TREATER.

WE HAVE TOLD THE TRUTH ABOUT OUR PRODUCT.

WE HAVE BEEN SINCERE.

OUR POLICY HAS SUCCEEDED.

SINCERITY IN BUSINESS IS AN ASSET.

WE HAVE FOUND IT SO.

The Reason:

Why a few plants have "standardized" on other alloys —

Why some still use Steel Boxes —

— is —

That they are unaware of the greater Economies and the Many Superiorities of —

Q-Alloys

It can not be said that any plant that has used Q-ALLOYS in production quantities has ever standardized on any other material. It is true that most plants that have "Standardized" on other alloys have made recent purchases of Q-Alloys for Comparison.

BOX BULLETIN SUPPLEMENT

FERRO-MANUREIUM

The Secret Ingredient

Krit Icklepoint completes extensive research, and solves great mystery which has baffled all chemists for generations

The unknown element in American Metallurgy and Chemistry discovered.

WALL STREET STOCKS TUMBLE

Note: This is positively the first news of this great discovery to reach the public. In copying credit Box Bulletin.

Krit Icklepoint, noted Authority has just completed extensive researches directed at the solution of the secret ingredient. For years, in fact since the first horticultural experiment of our forefathers, the "Secret Ingredient" had been a mystery to mankind. Many manufacturers claimed to have discovered it, crediting the discovery to salesmen of more or less standing, but no chemist has ever definitely analysed or discovered this "Secret Ingredient" until Krit Icklepoint made this startling discovery.

While the Rockefeller Foundation, and other worthy institutions of research have been squandering their millions in quest of the unworthy and elusive, Hook Worm, Krit, our stalwart Soldier of Science has fought consistently for his well merited achievement, the discovery of the "Secret Ingredient".

You've heard the steel salesman say "Our steel is tougher and harder than any other steel, its tensile strength exceeds that of similar steels, but you can't find any difference in analysis. One of our melters, imported from Sweden, has a secret ingredient which he adds in the ladle. His Great Grandfather discovered it and it has been handed from Father to son. We pay him a royalty. No competitor knows our secret, we are afraid to patent it, but it is this *secret ingredient* alone that makes our steel excel all others."

BOX BULLETIN SUPPLEMENT

You've heard the Iron Foundryman say "Our iron is entirely free from porosity, it flows more freely than any other iron. It shrinks uniformly in all sections. It is as tough as steel. Its physical properties are different from all other iron, and it is a cleaner metal. Yet there is no change in analysis. No Chemist can detect our secret. We use a secret deoxidizer. It is composed of many obscure chemicals, many of them entirely new. This secret ingredient burns up in the metal but not a trace can be found, and it does its work."

You've heard the Tire Salesman say "Our tires wear longer than any other tires. The whole secret is in our toughening compound. It makes the rubber twice as tough and three times more resilient than the best rubber produced by competitors. "But", you inquire, "Why don't your competitors use this wonderful compound?" "They can't", continues the Tire Salesman, "They can not find what it is, Chemists can't analyze it, it is made from rare elements that cannot even be found in a college course in Chemistry, however, its real success is due to just one magic mineral, a secret ingredient, discovered by the founder of our business. We lock it in the office safe and no one man knows all of the combination".

You've read the Gasoline literature. "Specific Gravity tests mean nothing, it's PEP that counts. Our Gas has more power in it, gives more mileage than any other Gas, keeps all carbon away, and makes spark-plugs last indefinitely. The secret of this wonderful gasoline is all in one small addition that we make in refining. It is made before the final stage of the process, and the vital radium-like material which we add is so completely mixed up in the gasoline that no chemist can find it." The *secret ingredient* does the work.

You've heard the Cutting Oil Salesman, but his argument is too lengthy to print. It has to do with the secret magnetic liquid which polarizes the atoms of lubricant, separates them from the atoms of non-lubricant, and utilizes the latter merely as a carrying medium to carry the useful atoms to the point where they are needed. One of his competitors has carried this wonderful process further and has made similar, but more extensive use of the electrons. All of these miracles being accomplished by the secret ingredient.

This "Secret Ingredient" is now definitely classified as FERRO-MANUREIUM. There are several classes of FERRO-MANUREIUM, but for the purpose of general classification we will place them under one head. The Symbols are B-s.

BOX BULLETIN SUPPLEMENT

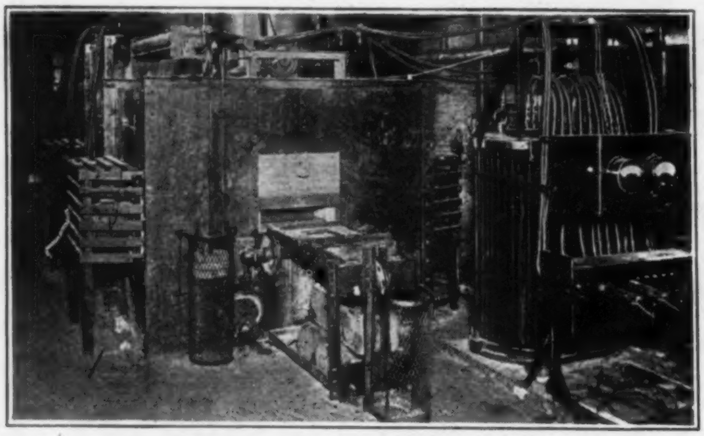
We have developed and produce Q-Alloys with the following points in mind:

1. Resistance to Oxidation—To Corrosion—Stability of surface with uniform resistance throughout entire section.
2. High Tensile Strength hot and cold through the entire range.
3. Serviceable to 2300° F. Capable of continuous operation at 2200° F.
4. Heat Conductivity.
5. Minimum Porosity.
6. Homogeneity—No segregation of component alloys.
7. Low Co-efficient of expansion.
8. Resistance to Action of Carburizing Compounds.
9. Fluidity in molten state which permits casting in all shapes desired.
10. Minimum shrinkage in mold to avoid cooling strains in metal.
11. Machinable.
12. Weldable.
13. Ductility to permit rolling into sheets.
14. General adaptability to all Heat Treating requirements.
15. Resistance to Carburizing. (No Carbon absorption).
16. Resistance to Cyanide and Lead.

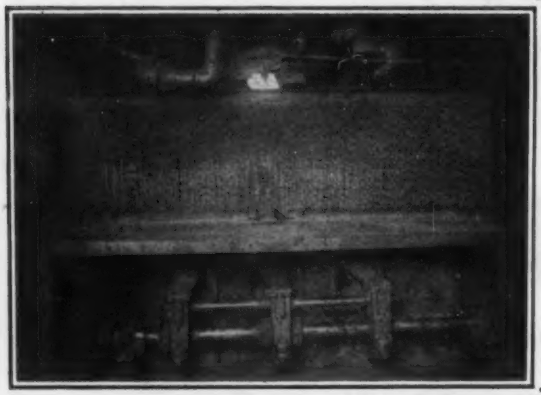
Q-Alloys do not warp, scale or crack and are guaranteed for use at temperatures in excess of 2200° F. They are obtainable in castings, sheets and drawn sections and are machinable and weldable.

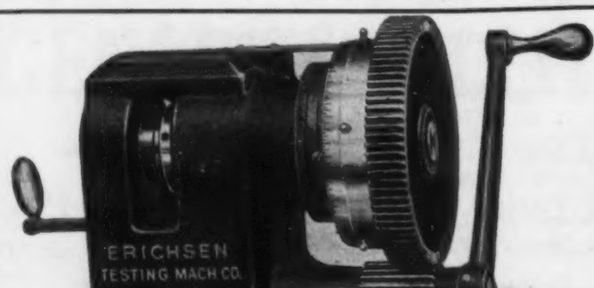
"Given the analysis, and physical properties of any 'Heat Resisting' alloy, we can advise you intelligently what may be expected from said alloy. There is no 'Genius' or 'Secrets' in the manufacture of these alloys, just Horse Sense, Precision, Good Faith and Application to business.

INSPECTION is responsible for the success of Q-Alloys."



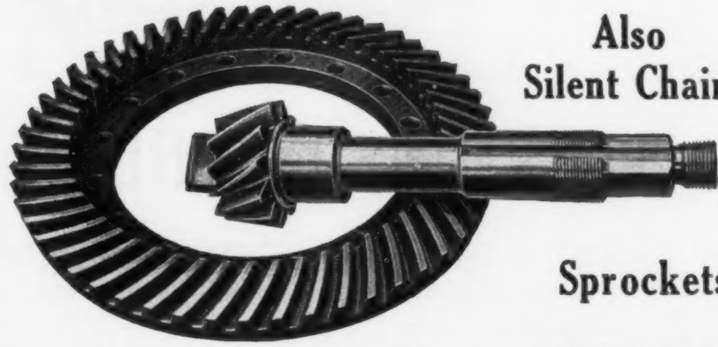
Electric Steel Treating Furnace insulated throughout with SIL-O-CEL





Spiral Bevel Gears

Automobile
Truck and
Tractor
Differential
and
Transmission
GEARS



Also
Silent Chain
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MIDWEST AIR FILTERS

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Turbo-generators
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and wherever dust is an objectionable feature.

Write for pamphlet ST, giving full particulars.

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Red Flame High Temperature Plastic Cement
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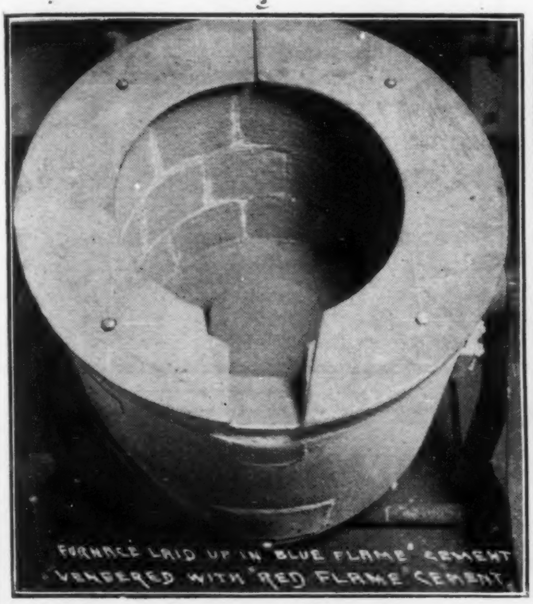
Plastik Do High Temperature Cement for Patching
"Ramit" Flame Brand High Temperature Ramming Cement

Flame Brand Cements Saved This Company $1341 a Month



Re-lined 15 Months Ago

As It Is Today—Good For 15 Months More

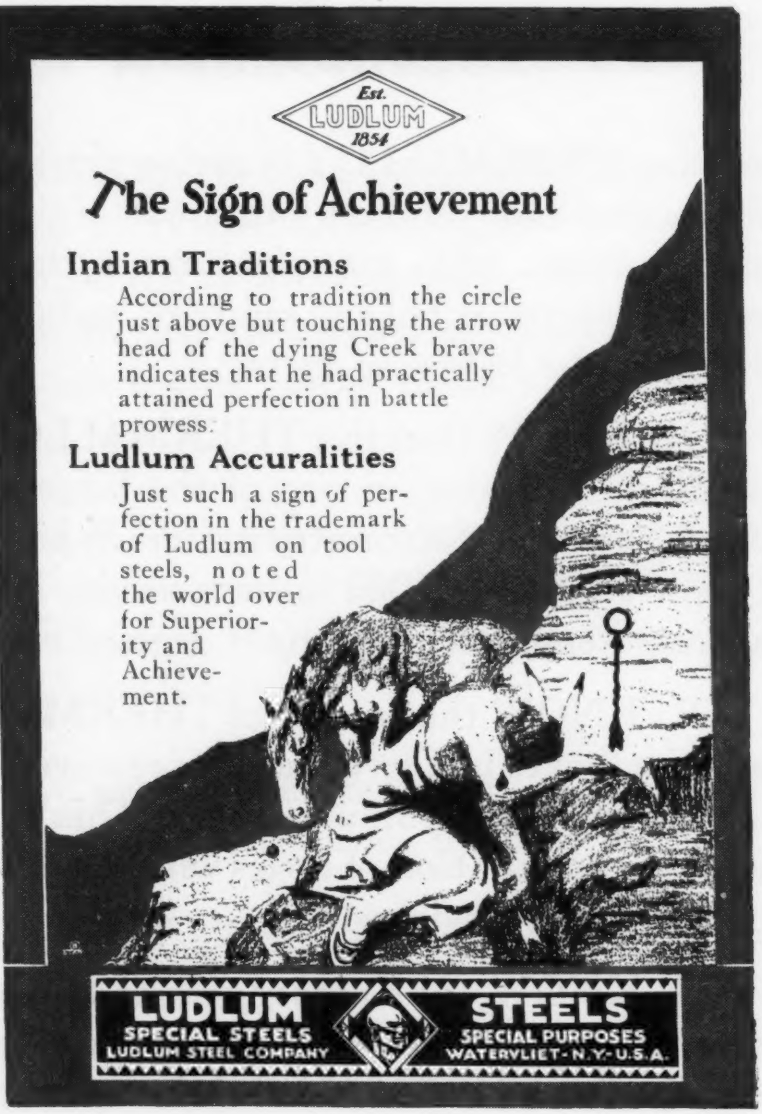
Here Are the Facts!

Number of Heats Obtained in Old Furnace	29
" " " " in Rebuilt Furnace	45
Saving on Fuel Consumption	$ 54.00
" " Cast Iron Pots	225.00
" " Labor	240.00
" " Power Consumption	70.00
" " Re-lining of Furnaces	452.00
" " Maintenance of Furnaces (Material)	120.00
" " Maintenance of Furnaces (Labor)	180.00
Total Saving	$1341.00

Let Us Be Your Furnace Doctors!

KING REFRACTORIES COMPANY, INC.

Main Office and Plant
1707-15 Niagara St. Buffalo, N. Y.
New York Office—705 Greenwich St.


Est.
LUDLUM
1854
The Sign of Achievement
Indian Traditions
According to tradition the circle just above but touching the arrow head of the dying Creek brave indicates that he had practically attained perfection in battle prowess.
Ludlum Accuralities
Just such a sign of perfection in the trademark of Ludlum on tool steels, noted the world over for Superiority and Achievement.
LUDLUM
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STEELS
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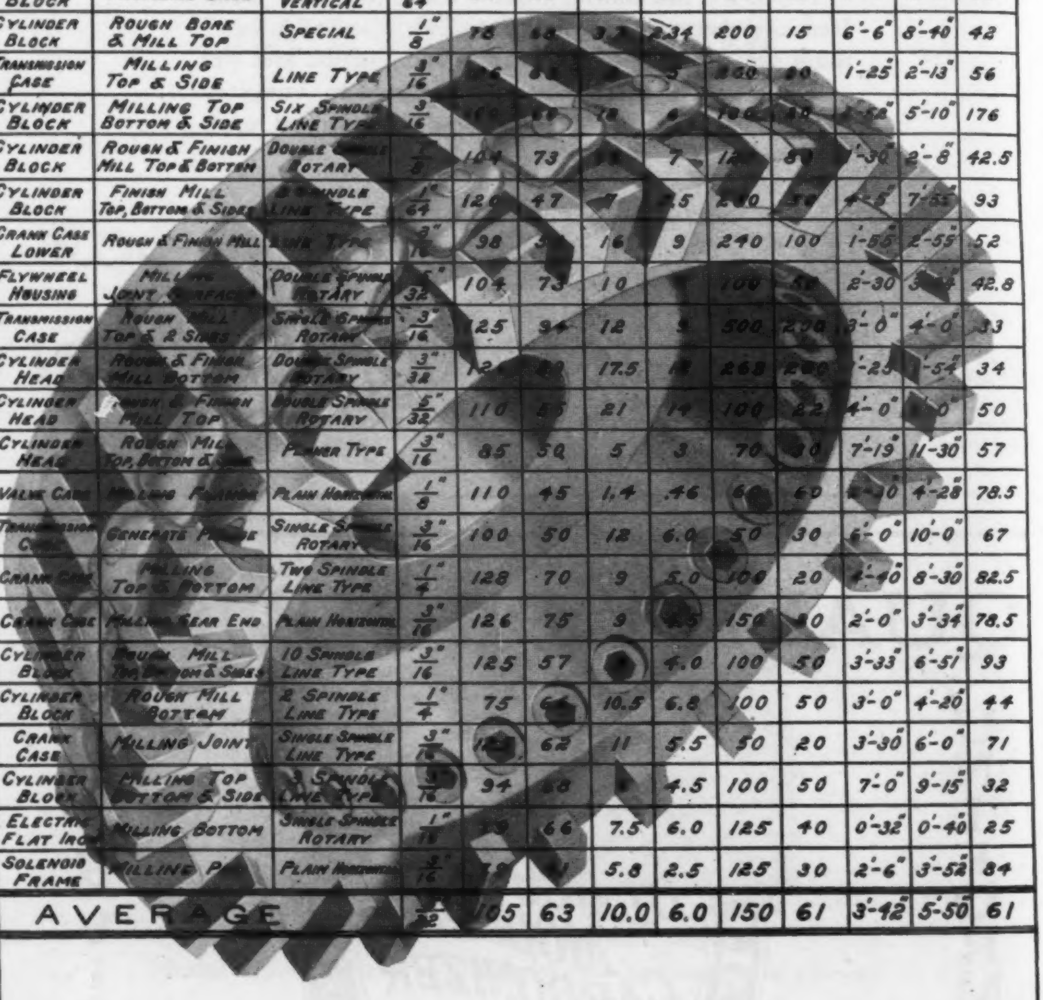
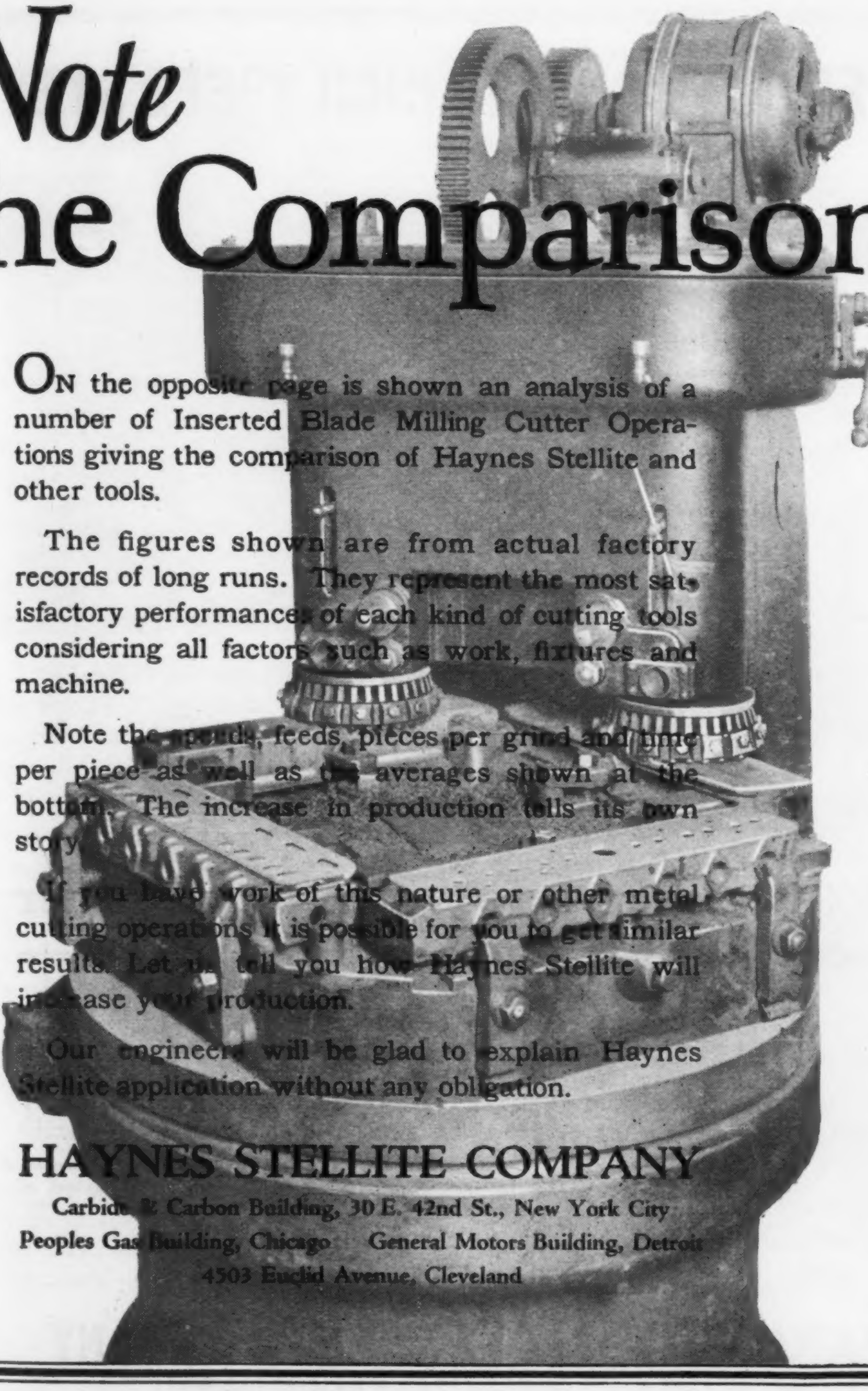
INSERTED BLADE MILLING CUTTER OPERATIONS



Part	Operation	Type of Milling Machine	Depth of Cut	Cutting Speed Feet per Min. — Haynes Stellite	Cutting Speed Feet per Min. — Other Tools	Feed per Minute Inches — Haynes Stellite	Feed per Minute Inches — Other Tools	Pieces per Grind — Haynes Stellite	Pieces per Grind — Other Tools	Time Floor to Floor — Haynes Stellite	Time Floor to Floor — Other Tools	Per Cent Increased Production
Cylinder Head	Rough & Finish Top & Bottom	Double Spindle Vertical	3/16"	114	92	15	12	173	30	6'-0"	7'-30"	25
Cylinder Block	Profiling Base	Single Spindle Vertical	1/64"	88	63	5.6	3.7	80	30	9'-0"	13'-11"	46
Cylinder Block	Rough Bore & Mill Top	Special	1/8"	78	66	[illegible]	2.34	200	15	6'-6"	8'-40"	42
Transmission Case	Milling Top & Side	Line Type	3/16"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1'-25"	2'-13"	56
Cylinder Block	Milling Top Bottom & Side	Six Spindle Line Type	3/16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5'-10"	176
Cylinder Block	Rough & Finish Mill Top & Bottom	Double Spindle Rotary	[illegible]	104	73	[illegible]	7	[illegible]	[illegible]	[illegible]-30"	2'-8"	42.5
Cylinder Block	Finish Mill Top, Bottom & Sides	[illegible] Spindle Line Type	1/64"	120	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93
Crank Case Lower	Rough & Finish Mill	Line Type	3/16"	98	[illegible]	16	9	240	100	1'-55"	2'-55"	52
Flywheel Housing	Milling Joint Surface	Double Spindle Rotary	5/32"	104	73	10	[illegible]	[illegible]	[illegible]	2'-30	[illegible]	42.8
Transmission Case	Rough Mill Top & 2 Sides	Single Spindle Rotary	3/16"	125	34	12	[illegible]	500	[illegible]	3'-0"	4'-0"	33
Cylinder Head	Rough & Finish Mill Bottom	Double Spindle Rotary	3/32"	[illegible]	[illegible]	17.5	[illegible]	268	[illegible]	[illegible]-25"	[illegible]-54"	34
Cylinder Head	Rough & Finish Mill Top	Double Spindle Rotary	5/32"	110	[illegible]	21	14	100	22	4'-0"	[illegible]	50
Cylinder Head	Rough Mill Top, Bottom & [illegible]	Planer Type	3/16"	85	50	5	3	70	[illegible]	7'-19"	11'-30"	57
Valve Case	Milling Flange	Plain Horizontal	1/8"	110	45	1.4	.46	[illegible]	60	[illegible]-30"	4'-28"	78.5
Transmission Case	Generate Flange	Single Spindle Rotary	3/16"	100	50	12	6.0	50	30	6'-0"	10'-0"	67
Crank Case	Milling Top & Bottom	Two Spindle Line Type	1/4"	128	70	9	5.0	100	20	[illegible]-40"	8'-30"	82.5
Crank Case	Milling Gear End	Plain Horizontal	3/16"	126	75	9	[illegible]	150	[illegible]	2'-0"	3'-34"	78.5
Cylinder Block	Rough Mill Top, Bottom & Sides	10 Spindle Line Type	3/16"	125	57	[illegible]	4.0	100	50	3'-33"	6'-51"	93
Cylinder Block	Rough Mill Bottom	2 Spindle Line Type	1/4"	75	[illegible]	10.5	6.8	100	50	3'-0"	4'-20"	44
Crank Case	Milling Joint	Single Spindle Line Type	3/16"	[illegible]	62	11	5.5	50	20	3'-30"	6'-0"	71
Cylinder Block	Milling Top Bottom & Side	3 Spindle Line Type	3/16"	94	[illegible]	[illegible]	4.5	100	50	7'-0"	9'-15"	32
Electric Flat Iron	Milling Bottom	Single Spindle Rotary	1/16"	[illegible]	66	7.5	6.0	125	40	0'-32"	0'-40"	25
Solenoid Frame	Milling P[illegible]	Plain Horizontal	3/16"	[illegible]	[illegible]	5.8	2.5	125	30	2'-6"	3'-52"	84
AVERAGE			[illegible]	105	63	10.0	6.0	150	61	3'-42"	5'-50"	61

HAYNES

Note the Comparisons



On the opposite page is shown an analysis of a number of Inserted Blade Milling Cutter Operations giving the comparison of Haynes Stellite and other tools.

The figures shown are from actual factory records of long runs. They represent the most satisfactory performances of each kind of cutting tools considering all factors such as work, fixtures and machine.

Note the speeds, feeds, pieces per grind and time per piece as well as the averages shown at the bottom. The increase in production tells its own story.

If you have work of this nature or other metal cutting operations it is possible for you to get similar results. Let us tell you how Haynes Stellite will increase your production.

Our engineers will be glad to explain Haynes Stellite application without any obligation.

HAYNES STELLITE COMPANY

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Peoples Gas Building, Chicago General Motors Building, Detroit
4503 Euclid Avenue, Cleveland

STELLITE
CUTTING TOOLS

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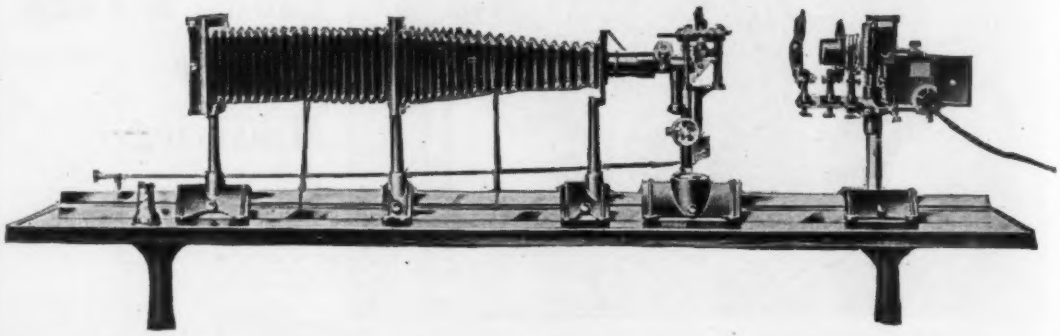
Leitz "Micro-Metallograph"

—Large Metal Microscope with Camera—



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